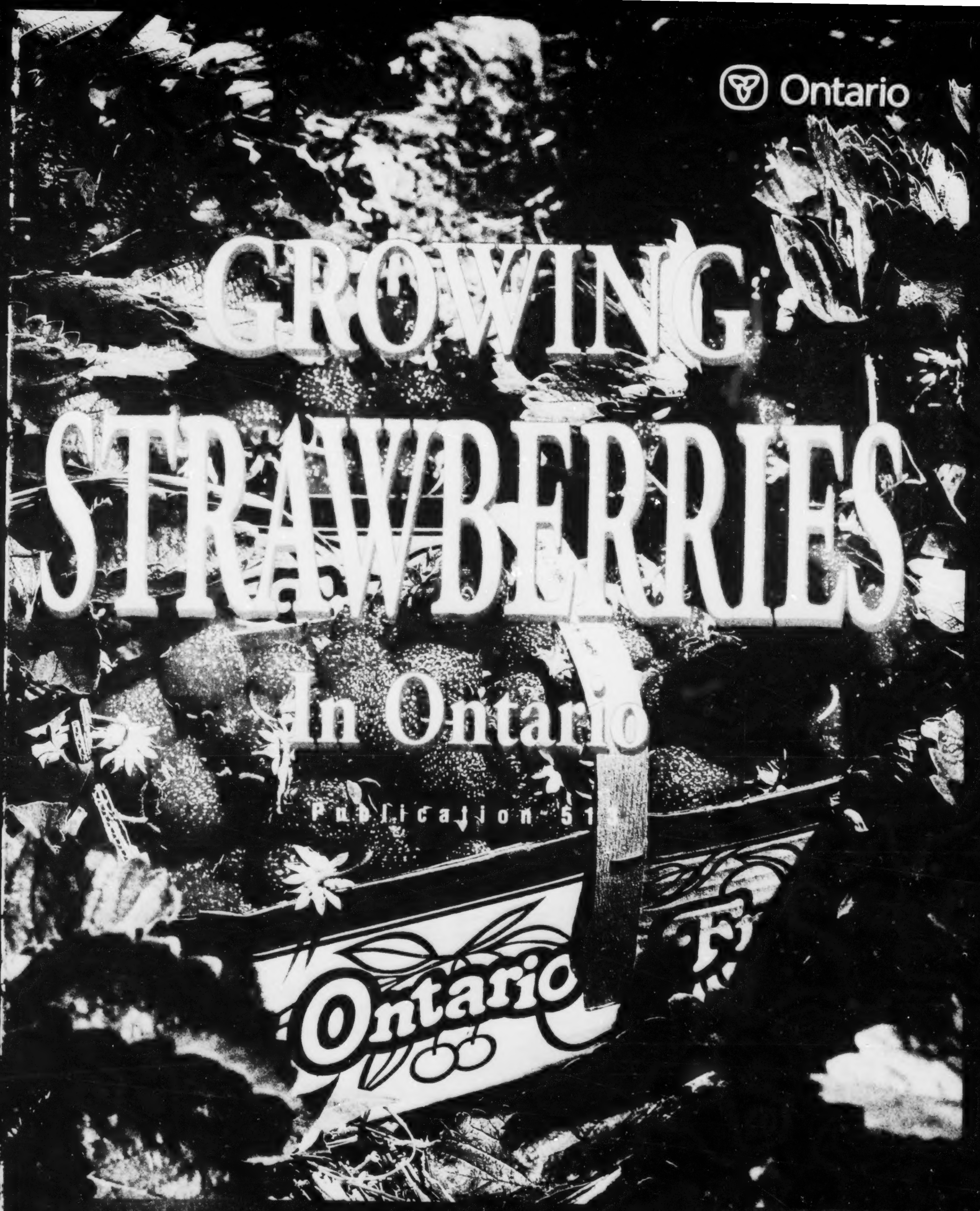
Ontario

GROWING STRAWBERRIES

In Ontario

Publication 51



MINISTRY OF AGRICULTURE, FOOD AND RURAL AFFAIRS

Growing Strawberries in Ontario
Publication 513

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1. Commercial Strawberry Production in Ontario

Introduction

Strawberries are an important fruit crop that can be grown successfully in many parts of Ontario. With an annual farm value of about $21 million (Ontario Horticultural Crop Statistics, 1994–98, OMAFRA) and a steady consumer demand, strawberry production can be profitable for Ontario growers. Like many high-value crops, strawberry production is a labour-intensive and high-risk enterprise. Marketing this perishable crop is intensive and challenging. Attention to detail is required at all stages of strawberry production, from planning, planting and crop management to managing crop pests, harvesting and marketing.

This publication, *Growing Strawberries in Ontario,* is designed to be a comprehensive resource for both new and experienced growers. It focuses on how the strawberry plant grows and is managed in Ontario conditions. With the basic understanding of how the strawberry plant works, the grower can improve crop management and explore different production systems. The strawberry varieties described in this publication have either performed well in Ontario or show potential for the future. Detailed chapters on strawberry pests emphasize the pest complex in Ontario and the best strategies for control.

Ontario Industry Trends

Several trends in the industry have occurred since the early 1960s.

- The annual commercial production average remained stable until the mid-1960s, then increased steadily until the mid-1980s. It dropped slightly between 1988 and 1992 but increased again with record production in 1995 (see Figure 1–1, *Strawberry Production in Ontario,* below).
- In the early 1960s, about 1,800 hectares of strawberries were grown in the province. From 1964 until 1969, the area in production was halved and did not start to recover until 1978. Since then it has increased steadily and has passed the early post-war levels (See Figure 1–2, *Strawberry Production Area in Ontario,* below).

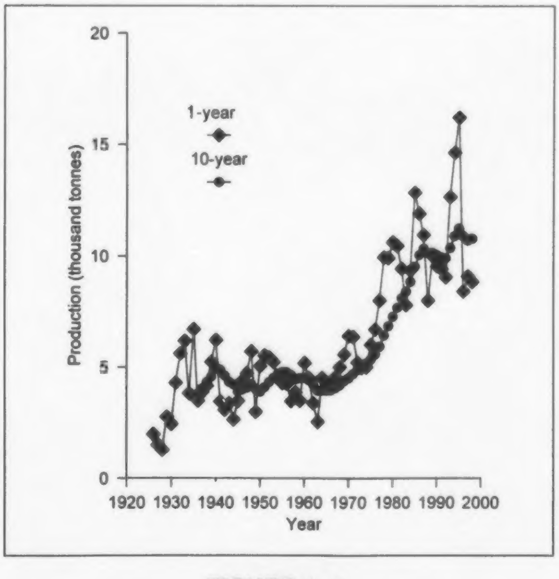


FIGURE 1–1.
Strawberry Production in Ontario
1- and 10-year moving averages from 1926–1995 (tonnes)

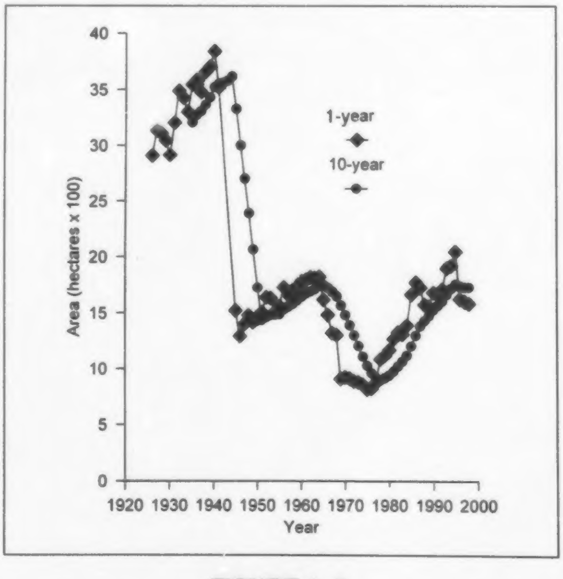


FIGURE 1–2.
Strawberry Production Area in Ontario
1- and 10-year moving average from 1926–1995 (hectares)

- Total production increased from 1968 to 1983 due to increased yield per hectare (see Figure 1–3, *Strawberry Yield/Hectare in Ontario,* below). Improved varieties, use of high-quality planting stock, improved cultural practices and better weed and pest control have given higher yields per unit area. Yield-per-hectare has declined from 1983 onwards, although the production area has increased steadily to give increased production. This may be due to saturation of the pick-your-own (PYO) industry, new varieties that are sensitive to the herbicides used and the public's demand for higher fruit quality. However, yields are affected greatly by weather, especially during the period when berries are developing.
- Production has increased in many areas of the province due to more pick-your-own operations near centres of population. However, in recent years, PYO production has met demand in many areas.
- Processing of Ontario-grown strawberries is a growing industry with about 500,000 kg of local berries processed in 1995.
- The average price of strawberries remained stable over the 20 years after the Second World War, and the price has steadily increased since the mid-1960s (see Figure 1–4, *Strawberry Prices in Ontario,* below).

Economics

According to OMAFRA statistics, the average commercial strawberry yield in Ontario was 7.3 t/ha (6,430 lb/acre) in 1995. Much higher yields than this have been reported, however, they fluctuate widely from year to year depending on weather conditions.

Prices received for PYO and for berries sold at the farm gate vary by region. For example, prices are often higher near large urban centres than in rural areas. Strawberries are a perishable, short-season crop, and these factors are also reflected in variable prices received during the harvest season. The price of strawberries is highest at the beginning and end of the season, when production in general is low, while it often drops in mid–harvest, when large quantities of berries are available and harvest is in progress in most areas.

Good records of input costs and revenues will help a commerical strawberry grower make informed decisions as to what varieties perform best, and when to stop cropping a particular planting.

The estimated costs of commercial strawberry production are available from the OMAFRA Web site, www.gov.on.ca/omafra, on the business development page.

"BEAR Plus" is a computer program that projects the profitability of proposed and present enterprises on the farm. It considers average yields and prices, and estimates costs of production. "BEAR Plus" budgets are available for strawberries, as well as for a number of other crops. Information on "BEAR Plus" and other financial management tools is available from OMAFRA.

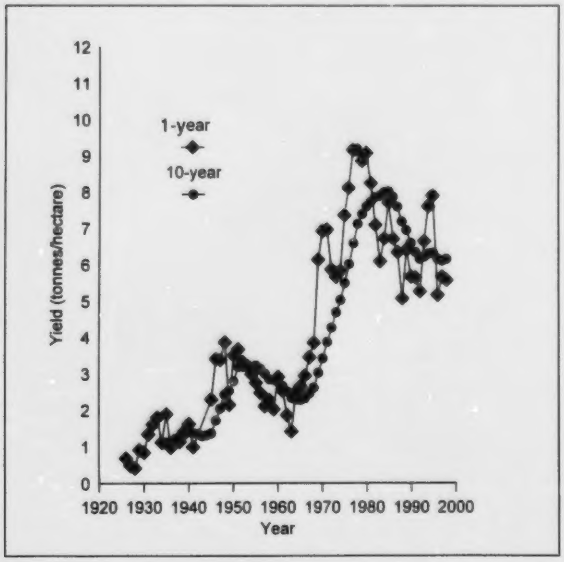


FIGURE 1–3.
Strawberry Yield/Hectare in Ontario
1- and 10-year moving average from1926–1995 (tonnes/hectare)

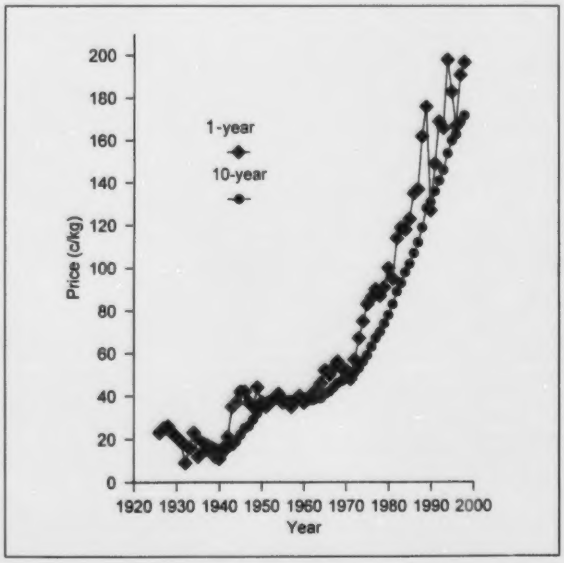


FIGURE 1–4.
Strawberry Prices in Ontario
1- and 10-year moving average from 1926–1995 (cents/kilogram)

Marketing

It is best to identify a market before strawberries are planted. Options for marketing strawberries include: pick-your-own, fresh market retail and wholesale sales, and processed and value-added products.

Many growers use more than one marketing method, because there are advantages and disadvantages associated with any single method.

Commerical growers should develop a marketing plan before they plant strawberries. Questions they should ask are: When will the berries be harvested and in what quantities? Who are the customers? What is a reasonable return on the product? What is the cost of production? Strawberries are perishable, and quality is extremely important. The marketing plan should account for all these factors.

Pick-Your-Own

From 40–45% of Ontario's strawberry production is marketed by PYO. This marketing method overcomes the problem of obtaining pickers and of handling, storing and shipping a perishable crop. Difficulties in getting all the crop harvested by PYO can occur when the weather is unfavourable for comfortable picking and the customers stay home.

Considerations

A successful pick-your-own operation depends on the demographics of the area, the location of the farm and the quality of the product and operation. For each acre of PYO strawberries, a population base of about 2,500 people within 32 km of the planting is needed (see Table 1–1, *Estimates of Population Base Required for a PYO Strawberry Operation,* above). A location on a paved road relatively close to a centre of population is desirable. Advertising to promote a pick-your-own business is less costly if a large customer base can reach the farm quickly and easily. A high volume of drive-by traffic is desirable for farm-gate sales.

A good advertising and promotion program can compensate for a more distant location. Begin advertising well in advance of the harvesting season. Inform people when the crop is ready, the hours the farm is open for picking and how to get there. Attractive signs leading to the farm, newspaper or radio advertisements and direct mailings are all effective methods of advertising, but satisfied customers provide the best advertisement.

A tourism-oriented directional sign (TODS) can be used on most Ontario highways to direct customers to your farm. These large blue signs give directions to tourist destinations, including farm markets and PYO farms. The signs are not designed for advertising but rather to get people off the highway to your place of business. To be eligible for a sign, your operation must be open for at least 12 consecutive weeks for at least 5 days a week. For more information, call Canadian TODS Limited at 1-888-263-9333.

TABLE 1–1.
Estimates of Population Base Required for a PYO Strawberry Operation

Population within a 32-kilometre radius of the farm (1,000's)	Maximum acres of berries than can be sustained for PYO in a 32-kilometre radius
5	2
10	4
20	8
30	11
40	15
50	18
60	21
70	24
80	27
100	30

Source: University of Illinois Cooperative Extension Service

A Pick-Your-Own directory is published each year. This directory can be used by consumers to find a PYO operation by location or by commodity. For information on how to have your farm listed in this directory, contact Bright Lights Communications, (416) 588-3390, or e-mail BrightLight@compuserve.com.

The Ontario Berry Growers' Association operates a hotline (1-800-263-3262) during the berry season. Callers can find out what farms are nearest them, and what picking is like that day. To have your farm listed with the Hotline, call the Ontario Berry Grower's Association at (905) 649-2101 (see Appendix B, *Organizations for Berry Growers,* on page 64).

Ample parking with safe access to and from public roadways is required (Plate 1). Other decisions that have to be made include whether to allow children in the field and how to organize and supervise picking, collect the payment for the berries, supply containers and provide drinking water and toilet facilities. Liability insurance is essential.

When customers have to travel fairly long distances to pick berries, the trip often becomes a family outing. Some growers stress the recreational and entertainment aspect of the PYO experience by providing play areas for children, snack bars and picnic areas.

Containers

Berries can be sold by volume or by weight. Selling by weight is more time consuming, but more fair to both the grower and the customer. About half of the PYO strawberries in Ontario are sold by weight.

Many growers sell containers to the customers. Customers tend to fill the containers they're picking into, so offering larger containers (e.g., 4-L baskets) will encourage them to pick more berries.

Customer Service

Growers who operate pick-your-own farms must have excellent communication skills and enjoy working with people or should hire staff with these qualities. Staff who meet the customers must be friendly, helpful and patient. Friendly and fair customer service will generate repeat sales.

Further information is contained in the OMAFRA Factsheet *Pick-Your-Own Harvesting*, Order No. 89–121.

Fresh Market Retail Sales and Wholesale

If berries are to be sold through retail or wholesale channels, they must be cooled quickly and sold soon after harvest. Being close to markets has many advantages. Storage and shipping times can be minimized, which reduces costs and maintains high berry quality.
Selling berries through fresh market channels requires considerably more attention to labour, containers and post-harvest handling practices than does PYO harvesting. Varieties that are well suited to PYO operations may not be suited to retail sales.

Considerations

Fifteen to 25 well-supervised people are needed to harvest 1 ha of berries, depending on their experience, the size of the crop and the rate at which strawberries are ripening. Most growers pay pickers by the quart or pound rather than by the hour. Attention to quality is required at all times during picking and post-harvest handling of the crop. Berries should be harvested every day or every second day, especially in hot weather. Rapid cooling within 2 hours of harvest is necessary to extend shelf life beyond one day. For more information on harvesting and post-harvest handling techniques, see the section on *Harvesting* on page 20.

Containers

Berries should be picked directly into the containers they will be sold in. Quarts or 2-L baskets are common for local retail sales. Most berries for wholesale markets are shipped in 6–8-quart masters. A logo or sticker can be incorporated into the container design to help identify the grower's high-quality product. This identification can become negative, however, if berries are not stored or handled properly after they leave the farm. Some wholesale buyers may require UPC codes on containers.

Buyers

Buyers should be contacted well before the harvest season to arrange ordering and shipping procedures. During the season when strawberries are abundant in Ontario, larger retail outlets and supermarkets will often feature strawberries at very low prices to attract customers to their store. These prices may be below the wholesale price and even below the cost of production. Growers who provide berries at wholesale prices should have an accurate idea of their cost of production. Buyers who expect quality berries that will ship and store well should be willing to pay for them.

Processed

The Ontario strawberry processing industry is currently limited by markets and competition from California, Mexico, the Pacific Northwest and Eastern Europe. Profit margins on processed strawberries are not high, and the cost of several months of cold storage can erode profits.

Less than 10% of Ontario-grown strawberries are used for processed products. Most of these are used to produce strawberry puree for yogurt and ice cream, or may be frozen, sliced or whole, in a sugar pack. The technology for processing berries continues to improve. Varieties and production systems have been developed that could be adapted to mechanical harvesting.

If berries are to be marketed for processing, it is advisable to obtain contracts before harvest. An agreement with the processor should specify the type of pack required, the varieties, quantities, price and delivery procedures.

Value-Added

Growers with retail outlets and access to freezers can freeze berries that might otherwise go to waste during the peak of the season. Jams and jellies can also generate a higher profit margin than fresh fruit, but input costs are also high. Careful attention to sanitation at every step is required for all value-added products. Labelling requirements must also be met.

Promotion

These three excellent organizations can assist Ontario berry growers with promotion and marketing ideas for their crops (see Appendix B, *Organizations for Berry Growers*, on page 64):

- The Ontario Berry Growers Association
- The Ontario Farm Fresh Marketing Association
- The North American Strawberry Growers Association

2. The Strawberry Plant

The strawberry plant is a low-growing perennial. The daughter plants, produced on runners from the mother plants, are used to establish fruiting fields.

The plant consists of a short, stocky stem or crown with short internodes. Roots grow from this crown to hold the plant into the ground (see Figure 2–1, *Mature Strawberry Plant With Runner at Flowering,* below). The crown has large, trifoliate leaves. Buds at the bases of the leaves can grow into new branch crowns, runners or fruiting trusses.

Root Development

The primary roots initiate adventitiously behind the leaf bases on the crown (see Figure 2–2, *Root Distribution of Mature Strawberry Plant,* below). When the primary roots are 2–5 cm long, they start to develop secondary branch roots. These can branch to give the mature root system its typical "matted" look. A mature plant usually has 20–35 primary roots but may have as many as 100. These roots are mainly in the top 15 cm of the soil. Between 25–50% of the roots are found in the top 7.5 cm, 25–40% in the next 7.5 cm and the remainder usually in the next 30 cm. Roots can be found to a depth of 100 cm, particularly in sandy soils.

In a plant of any age, the main feeder roots will be white. These roots can absorb water and nutrients from the soil. As they age, they become suberized, and are no longer able to absorb water and nutrients.

For new roots to develop properly, they must contact moist soil. Typically, in dry soils or air, the plant produces short peg roots that will only develop when in contact with moist surfaces. On the other hand, a soil that is water-logged will inhibit the production of new feeder roots, and older roots may be invaded by soil-borne pathogens.

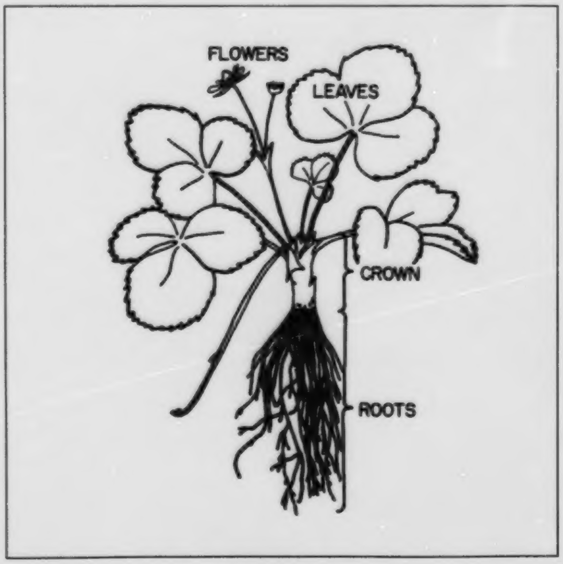


FIGURE 2–1.
Mature Strawberry Plant With Runner at Flowering
(Reproduced by permission of M.N. Dana)

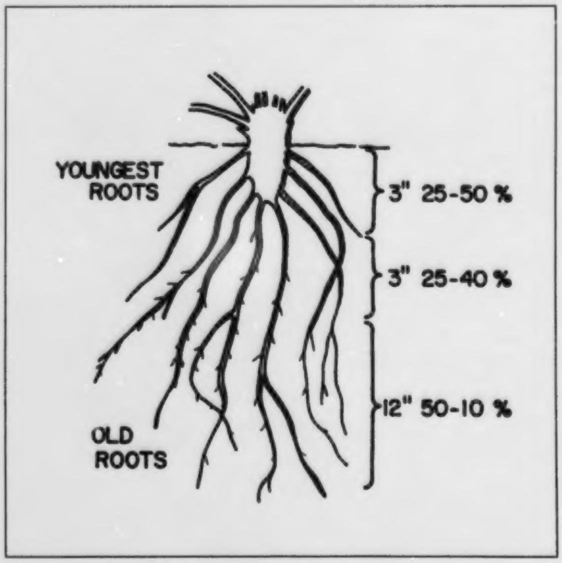


FIGURE 2–2.
Root Distribution of Mature Strawberry Plant
(Reproduced by permission of M.N. Dana)

Crown Development

The crown is a woody main stem with shortened internodes (see Figure 2–3, *Elongation of a Strawberry Crown,* below). At the tip of the crown is a terminal meristem that produces new buds and leaves as it grows. Between each leaf and the main stem is a dormant bud. This can develop into a floral stem, a branch crown or a runner, depending on the time it was initiated and the season of the year. New leaves are produced every 8 to 12 days when the plant is actively growing. This rate depends on the temperature and is fastest between 20°C and 27°C. The leaves live for 1–3 months, and when they die, their leaf base remains attached to the main stem. Mature crowns can be distinguished from younger crowns by their leaf bases.

Some of the buds on the crown will develop into branch crowns. This usually happens in the shorter days of late summer or fall, coupled with warm weather. The ability of varieties to form branch crowns depends on environmental conditions. For example, the variety Kent tends to form more branch crowns in the warmer areas of southwestern Ontario than in the cooler areas of central-northern and eastern Ontario.

The crown is composed of three morphological zones: a large central pith, a thin layer of vascular tissue and an outer cortical and epidermal zone. The outer epidermis protects the crown, the vascular tissue is responsible for transporting nutrients to and from the root system and the central pith is used to store water, carbohydrates and nutrients.

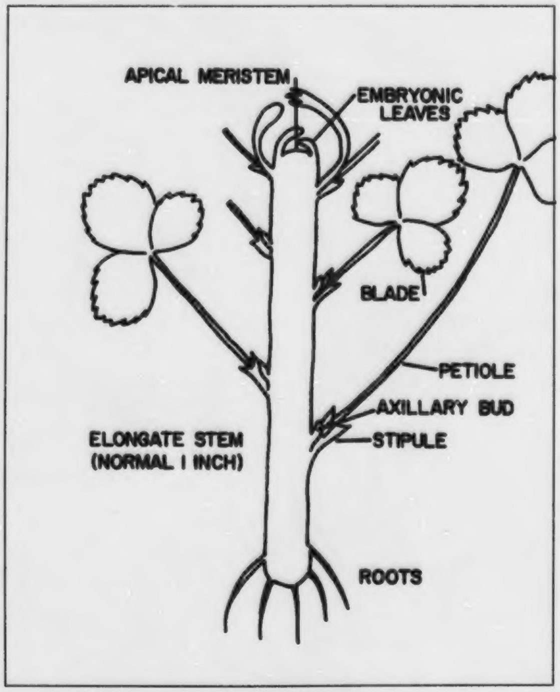


FIGURE 2–3.
Elongation of a Strawberry Crown
(Reproduced by permission of M.N. Dana)

Runner Formation

When the days are long, the axillary buds on the crown can develop into elongated, above-ground runners. Typically, the first two internodes of the runner are very elongated, and the third and subsequent internodes develop into a daughter plant (see Figure 2–4, *Strawberry Crown With Runner,* below). Axillary buds on the daughter plants can produce runners, as can the first node on the runner. An actively growing plant can produce 10 to 15 runners in a season. These then produce a succession of secondary runners; a plant can produce up to 100 daughter plants during the growing season. The daughter plants will be of different ages, depending on their position relative to the mother plant and will continue growing actively until the fall. The oldest daughter plants will have the largest crowns and the highest potential for fruit production and vegetative growth in the following season.

Once a runner has produced a new daughter plant, it continues to function as a transportation organ and transports water, organic nutrients and carbohydrates to the developing plant.

Flower and Fruit Development

The flower cluster or inflorescence initiates in the terminal meristem under conditions of certain temperatures

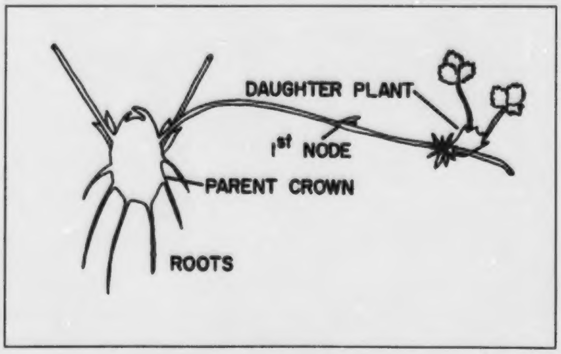


FIGURE 2–4.
Strawberry Crown With Runner
(Reproduced by permission of M.N. Dana)

and length of days (see Figure 2–5, *Flower Cluster Development on Main Axis and Branch Crown,* right). It develops on a main stem, which is called a scape or peduncle. The main axis of the scape bears a terminal flower and two bracts that bear branches opposite each other part way down. These secondary branches have the same structure as the main branch — a terminal flower and two branches — and this is repeated up to three more times so that there can be five levels of flowers (see Figure 2–6, *Structure of a Typical Strawberry Flower Cluster,* right). There can be up to 31 flowers on the flower cluster, 1 primary, 1 secondary, 4 tertiary, 8 quaternary and 16 quinquinary. The primary flower is the first to open, and the quinquinaries the last. However, any one flower cluster may be made up of fewer than these. For instance, a flower cluster can develop with 1 primary, 1 secondary, 2 tertiary and 4 quaternary berries only.

The flower consists of a central receptacle that supports the pistils, stamens, petals and, on the outside, sepals (see Figure 2–7, *Structure of a Typical Strawberry Flower,* right). The pistils contain the ovule or egg, and the anthers contain the pollen. When the anthers are mature, they split, and the pollen grains are released. They land on the stigma where they germinate and fertilize the ovule. The fertilized ovule then grows to become an achene (see Figure 2–8, *Structure of a Strawberry "Fruit",* right). The achene is the true fruit of the strawberry and contains the seed. The fleshy fruit that we know is merely the growth of the receptacle under the achenes. The achenes must develop normally because if they do not, the fleshy receptacle, or fruit, can become deformed. Severe deformations make the fruit unmarketable.

Flower and fruit size are determined during the development of the flower and are closely related to the number of pistils on the receptacle. The primary flower may have up to 400 or more pistils, the secondaries 200–300, the tertiaries 50–150 and the quaternaries and quinquinaries even less. The developing achenes secrete plant hormones that cause the cells in the receptacle to increase in size to become the "berry."

Pollination is assisted by wind or insects. The pollen is light and is easily blown by the wind, but studies have shown that insects improve pollination.

The time it takes for fruit to mature, that is, from pollination to ripe fruit, is generally considered to be about 30 days. High temperatures can shorten this to less than 20 days, and cool temperatures can lengthen it to up to 60 days. The berry will continue to enlarge until it fully ripens. It then holds its size as it becomes

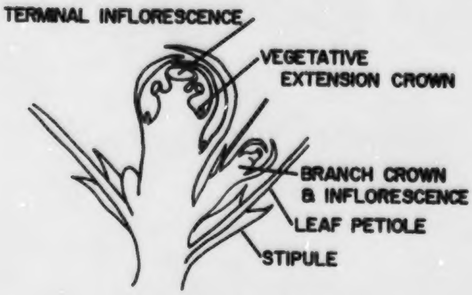


FIGURE 2–5.
Flower Cluster Development on Main Axis and Branch Crown
(Reproduced by permission of M.N. Dana)

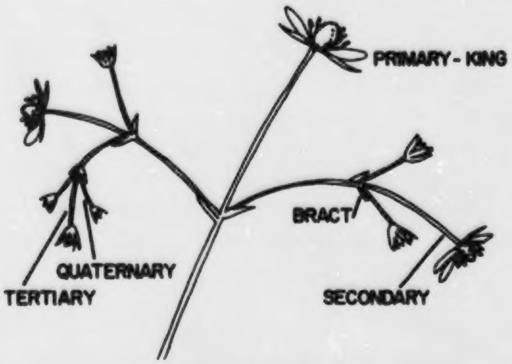


FIGURE 2–6.
Structure of a Typical Strawberry Flower Cluster
(Reproduced by permission of M.N. Dana)

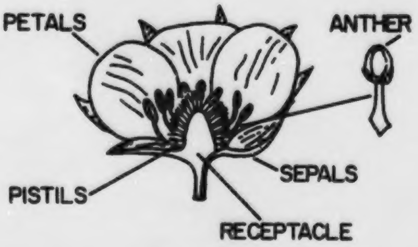


FIGURE 2–7.
Structure of a Typical Strawberry Flower
(Reproduced by permission of M.N. Dana)

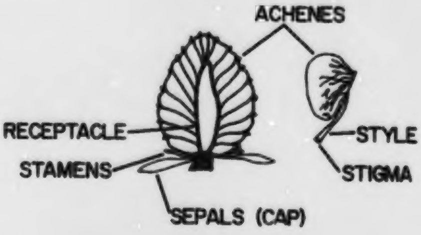


FIGURE 2–8.
Structure of a Strawberry "Fruit"
(Reproduced by permission of M.N. Dana)

over-ripe, at which stage it will shrink as moisture is lost from the flesh.

Plant Responses to Temperature and Day Length

Various phases of plant development, bud initiation, dormancy, flowering, runner formation and branch crown development are triggered by changes in temperature and day length. In Ontario, strawberry plants initiate flower buds in late August that continue developing until the plants become dormant. Cool, short days in the fall cause the plants to initiate flower buds, harden for the winter and become dormant. The flower buds develop, the crown of the plant grows rosettes with smaller leaves protecting the crown, starch is stored in various parts of the plant and the plant becomes capable of withstanding below-freezing temperatures.

The plant then remains dormant during the sub-freezing temperatures of winter and when the temperatures rise in the spring, it begins a period of rapid growth. Although the plant is inactive during the winter, it continues to be conditioned by what are termed "chilling hours." The plant needs a certain number of hours below 7°C to switch from the dormancy phase to the rapid growth of spring. Failure to obtain the chilling hours results in scapes that produce fewer flowers and plants that grow more slowly.

In the spring, the plant grows rapidly, producing new roots and leaves. The flowering scape elongates rapidly, flowers open and the fruit develops. Then, in the warm, long days of summer, the runners start to form, and later, the branch crowns form.

There are different types of flowering in strawberry varieties that complicate the life cycle of the plant. The different types are referred to as June-bearers, ever-bearers and day-neutrals.

In June-bearing plants, the flower buds initiate during the cool temperatures and shorter days typical of the fall. After a period of cold acclimation, they grow rapidly in the spring and fruit in late June to early July.

Ever-bearers have the capacity to also initiate flowers during periods when the days are long. They produce two crops, one in the spring and a second in the fall.

Day-neutrals have the capacity to initiate flowers no matter what length the day is. Hence, a day-neutral plant grown outdoors will produce three cycles of flowers, which leads to a continual crop of fruit throughout the summer. Day-neutrals grown in a greenhouse or protected environment can be fruited continually, beginning about 3 months after planting and continuing as long as growing conditions are suitable.

3. Culture

The Year Before Planting

Choosing a Location

Strawberries are grown commercially in most of Ontario. The main factors that determine whether a location is suitable for commercial production are:

- the presence of suitable sites
- the availability of markets
- adequate labour supply for harvest

These factors are more important than climatic conditions when a location is selected for planting, although labour supply may not be a factor if berries are marketed by the pick-your-own method (see Figure 3–1, *Considerations Before Planting Strawberries,* on page 10).

Site Selection

When a site is selected for planting, consider soil type, surface water drainage, air drainage, availability of water for irrigation, exposure and previous crops.

Soil

Strawberries can be grown on a wide range of soil types — from sandy to clay loams with at least 2% organic matter. However, deep sandy loams that are well supplied with organic matter will produce the best yields. The soils must be well drained, yet hold moisture well. Soil pH should be between 5.8 and 6.5.

Coarse and gravelly soils should be avoided. They are infertile and subject to drought. Optimal fertilization and irrigation are required to achieve high yields on these soil types.

Soils with a high clay content should also be avoided. Clay soils are usually poorly drained and difficult to manage. Good soil drainage is needed, as strawberry roots will not tolerate a saturated soil. Tile drains may be required to improve soil drainage. Hardpans, or hard-packed layers of soil, can occur beneath the soil surface and prevent good drainage. These can be broken up by subsoiling.

Surface Water Drainage

The field should be free of depressions with enough slope that surface water drains away quickly. Strawberries become injured if standing water is present even for a day or two. This is especially true when plants are actively growing.

In the winter, water that collects in poorly drained areas freezes and causes the suffocation of plants. Shallow ditches may be used to drain low areas. On moderate slopes, strawberries should be planted on the contour to prevent soil erosion. Steep slopes should not be used.

Air Drainage

The perimeter of a planting site should be free from obstructions (thick hedgerows, woods, buildings, raised roadways, etc.) that will interfere with good air drainage from the lower end of the field. With good air drainage, the cold air will not settle over the site but will move to lower land. This will reduce the risk of damage from spring frosts and winter injury. Frost control is discussed in the section on *Frost Injury and Protection* on page 25.

Exposure

On sites with a southern slope, plants begin to grow, and berries ripen earlier than on sites sloping to the north. This is useful if berries are needed for early markets. However, because growth is earlier, the risk of spring frost injury is greater on a southern slope.

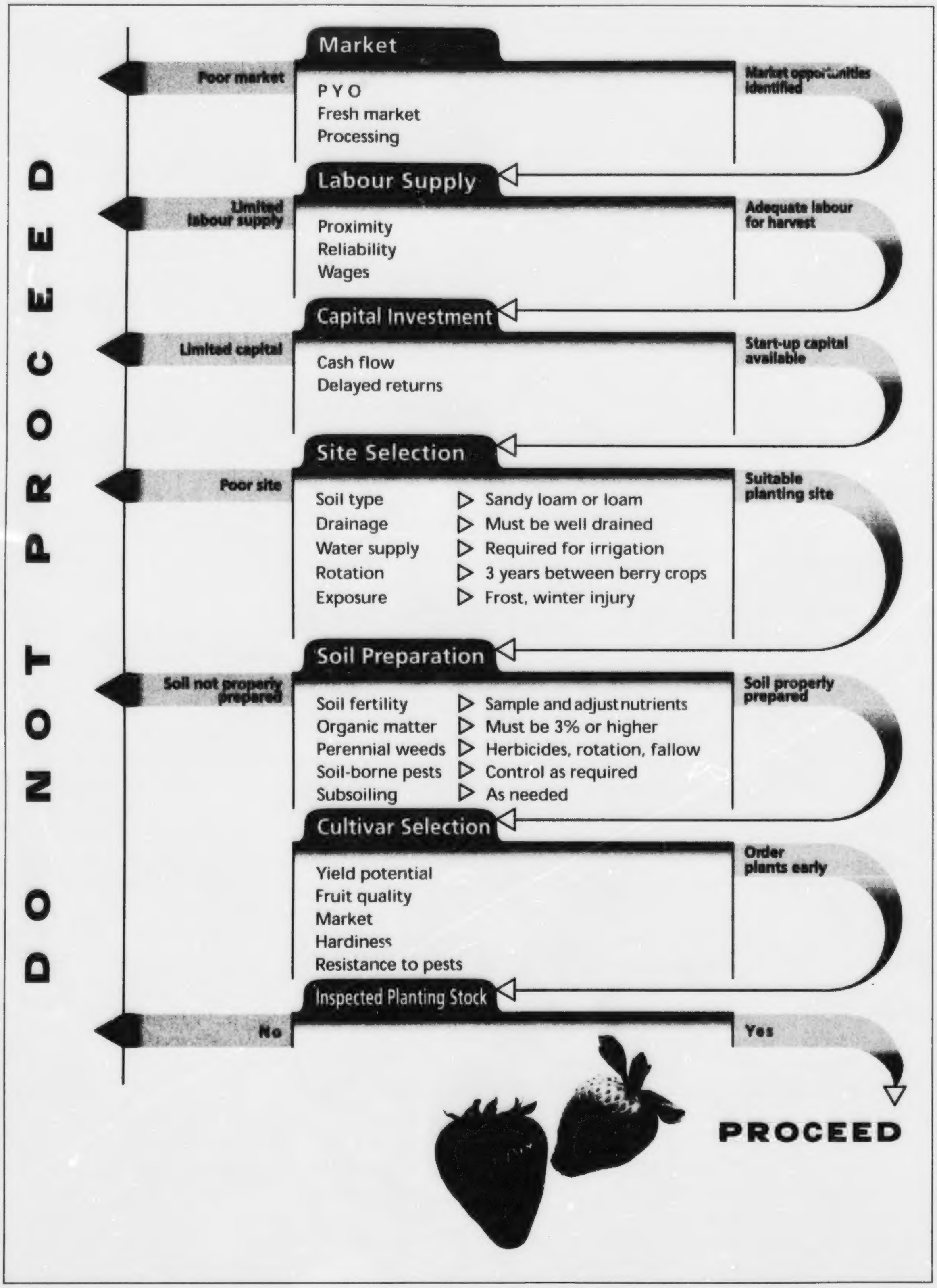
Water for Irrigation

Irrigation is essential for consistently high production. There are very few seasons when irrigation is not needed. When a site is selected, a suitable water supply for irrigation must be available. Irrigation is discussed further in the section on *Irrigation and Frost Protection* on page 23.

Wind Breaks

On windy sites, a windbreak can help bring about earlier ripening, prevent strong winds from drying out plants and prevent mulch from blowing out of place. However, a windbreak should not be so dense that it prevents good air drainage. An ideal windbreak density should consist of 50% physical barrier (trunk, branches, leaves, needles) and 50% air space and should not have large, visible holes or empty spaces from missing trees. Where there is a risk of frost injury and management of strong winds is required, windbreaks should be located along the west and north edges of berry plantings without blocking air drainage out-

FIGURE 3–1.
Considerations Before Planting Strawberries


DO NOT PROCEED
Market
Poor market
PYO
Fresh market
Processing
Market opportunities identified
Labour Supply
Limited labour supply
Proximity
Reliability
Wages
Adequate labour for harvest
Capital Investment
Limited capital
Cash flow
Delayed returns
Start-up capital available
Site Selection
Poor site
Soil type ▷ Sandy loam or loam
Drainage ▷ Must be well drained
Water supply ▷ Required for irrigation
Rotation ▷ 3 years between berry crops
Exposure ▷ Frost, winter injury
Suitable planting site
Soil Preparation
Soil not properly prepared
Soil fertility ▷ Sample and adjust nutrients
Organic matter ▷ Must be 3% or higher
Perennial weeds ▷ Herbicides, rotation, fallow
Soil-borne pests ▷ Control as required
Subsoiling ▷ As needed
Soil properly prepared
Cultivar Selection
Yield potential
Fruit quality
Market
Hardiness
Resistance to pests
Order plants early
Inspected Planting Stock
No
Yes
PROCEED

lets. To increase air movement near the ground and prevent frost pockets near the tree row, selectively remove a portion, but not all, of the lowest branches from the windbreak (20% barrier:80% space), 4–6 ft above the ground. Avoid completely removing all branches near the ground since wind travelling through this space will increase to extremely high speeds due to a bottleneck effect caused by high air pressure windward to the tree row. A proper windbreak will provide protection from extreme winds for a distance equal to 10 to 15 times the height of the windbreak. For example, a windbreak maintained at 10 ft will provide 100 to 150 ft of downwind protection for the berry crop.

Previous Crops

Strawberries should not be planted frequently on the same site, because nematodes and diseases will increase in the soil.

New strawberry plants should not be grown in soils where other strawberries, raspberries, potatoes, tomatoes, peppers or eggplants have been grown in the previous 4 or 5 years. These crops are susceptible to verticillium wilt. This disease is caused by a fungus that builds up when these crops are grown often on the same soil. Many strawberry varieties are quite susceptible to verticillium wilt and perform very poorly when infected. Verticillium wilt may also be a problem when strawberries are planted after removal of an old peach crop or cherry orchard.

If the site intended for strawberries is a pasture or sodded area, white grub populations may be high. To prevent problems, soil should be worked up and a cultivated crop grown for 2 years before planting strawberries.

The crops that fit best in rotation with strawberries will be determined by the individual grower. One consideration is whether herbicides used on one crop in the rotation are likely to injure one of the other crops. For example, application of terbacil (Sinbar) to strawberries can leave soil residues that could injure following crops. Soil residues of atrazine applied to corn over several years could injure strawberry plants. Atrazine residues from a single application of 1.5 kg a.i./ha to corn should not harm newly planted strawberries the following year. Other herbicides with long residual activity, such as imazethapyr (Pursuit) used on soybeans and white beans, may also be harmful to strawberries. Herbicide programs may need to be adjusted to permit successful crop rotation.

In some cases, it may not be practical to follow a 4–5- year rotation. When rotations are shortened to 2–3 years, plant varieties that are tolerant to verticillium (see Table 4–2, *Strawberry Variety Ratings for Resistance to Diseases,* on page 34). Soil fumigation should be considered (see the section on *Soil Fumigation* on page 13), and growers should watch closely for problems, such as root rot, verticillium wilt, red stele, root weevils, nutrient deficiencies, etc.

Soil Preparation

High yields (15,000–17,000 kg/ha) can be achieved only where growers carefully prepare the soil before they plant. Strawberries are shallow-rooted plants, and heavy demands are placed on the root system, especially in the short period when berries are developing. The soil must be in excellent condition throughout the duration of the planting. It must be well supplied with readily available nutrients, have a high moisture-holding capacity and yet be loose and well drained. Careful attention to these details the year before planting will minimize problems in the cropping years.

Soil preparation should begin at least the year before planting in order to:

- adjust soil pH and nutrients to optimum levels
- add as much organic material as possible and allow it to decompose by planting time
- control weeds (especially perennials)
- reduce nematode populations below threshold levels

Soil Fertility

A pre-plant soil test should be taken to determine the soil pH, organic matter content and the phosphorous, potassium and magnesium requirements of the soil (see Table 3–1, *Phosphorous and Potassium Requirements for Strawberries,* on page 12). Soils should be sampled 15–30 cm deep from several sites to represent the field. Instructions for sampling and a list of accredited soil testing laboratories are available in OMAFRA Publication 360, *Fruit Production Recommendations,* and on the OMAFRA Web site at www.gov.on.ca/omafra/english/crops.

Strawberries grow best at a soil pH of about 6.5. A soil pH below 5.6 on clay loam and below 6.1 on sandy loam should be adjusted upwards by lime applications the year before planting. When soil pH is above 6.8, micronutrients become less available.

Information on the nutrient requirements of strawberries can be found in OMAFRA Publication 360, *Fruit Production Recommendations.* This publication is reviewed annually and should be consulted for the most current recommendations for strawberries.

Organic Matter

Soil organic matter is an important key to high yields. Organic matter increases the moisture-holding capacity

TABLE 3–1.
Phosphorous and Potassium Requirements for Strawberries

Phosphorous				Potassium		
Soil Test (ppm P)	Rating	Phosphate Required kg P_2O_5/ha		Soil Test (ppm K)	Rating	Potash Required kg K_2O/ha
		New Plantings	Established Plantings			
0–3	Low	140	100	0–15	Low	130
4–5		130	90	16–30		120
6–7		120	80	31–45		110
8–9		110	70	46–60		100
10–12		100	70	61–80		90
13–15		90	60	81–100		80
16–20	Medium	70	50	101–120	Medium	70
21–25		60	40	121–150		60
26–30		50	30	151–180		40
31–40		40	20	Above 180	High	0
Above 40	High	0	0			

of sandy soils. It maintains or improves soil structure by binding together soil particles into groups or aggregates. This results in a loose soil with good drainage, aeration and water penetration — conditions that favour rapid and extensive rooting. Organic matter also helps somewhat in retaining nutrients against leaching loss, and in releasing them gradually through the growing season. Soils should have at least 2–3% organic matter.

There are several ways to add organic matter to soil. A cover crop grown the year before planting strawberries can supply additional organic matter for the strawberry crop (Plate 2). Various crops are suitable, and those that suppress nematodes are preferred (see Table 3–2, *Characteristics of Cover Crops Grown in Ontario,* on page 13). Fertilize the cover crop according to a soil test. Supplemental nitrogen may be required to maximize the growth of the cover crop. Control weeds so good growth occurs. Work the green-manure crop into the soil before it goes to seed and in time for it to decompose before planting. When the cover crop is ploughed down, apply about 30 kg/ha of nitrogen to help it decompose. If a legume cover crop was used, extra nitrogen is not required. The legume itself will provide sufficient nitrogen for its decomposition plus some for the strawberry plants that follow.

Manure can be a good source of organic matter and also provides some nutrients. However, manure is extremely variable in dry-matter and nutrient contents. An application of up to 45 t/ha of cattle or swine manure containing bedding material can be beneficial, especially if a cover crop has not been used and if no other organic matter has been added recently. Well-composted manure that is free of weed seeds may be applied in the spring of the planting year. Otherwise, manure should be applied the previous fall and worked in. This allows time for it to decompose partially before planting and allows weed seeds to germinate so they can be destroyed. If poultry manure is used, apply no more than 10 t/ha well ahead of planting. Fresh poultry manure can burn strawberry roots.

Other organic materials, such as fruit and vegetable processing waste or compost, may also be added to the soil as organic matter. A permit from the Ontario Ministry of the Environment is required when organic matter is from off-farm sources.

Weed Management

Perennial weeds such as quack grass, thistles, bindweed, horsetail, nutsedge and others should be completely eliminated before strawberries are planted. These weeds are extremely difficult to control in strawberries and will quickly result in lost production and shorten the life of the planting. Summer fallowing combined with cover crops can reduce perennial weed problems. Certain weeds such as yellow nutsedge and field horsetail are best controlled by rotation into corn or beans where herbicides that control these weeds can be used. Between crops, systemic herbicides such as Round-up can be used as spot treatments for selective weed control. Repeated applications may be required until no new regrowth occurs. Refer to OMAFRA Publication 75, *Guide to Weed Control,* under the sections on *Special Methods of Weed Control, Pre-Plant Site Preparation* and *Spot Treatment.*

A cover crop that smothers weeds the year before planting will help reduce weed populations as well as improve soil fertility and structure. Selective herbicides, like 2,4-D, can

TABLE 3–2.
Characteristics of Cover Crops Grown in Ontario

Species	Normal Seeding Time	Seeding Rate kg/ha	Nitrogen Fixed	Overwintering Characteristics	Potenial Weed Problem From Volunteer Seed	Supports Nematodes[1]	
						Lesion	Root-knot
Grasses							
Spring cereal	Mid-Aug.–Sept.	100–125	no	killed by heavy frost	no	+	–
Sorghum sudan	June–Aug.	50	no	killed by frost	no	0	–
Winter wheat	Sept.–Oct.	100–125	no	overwinters well	no	+	–
Winter rye	Sept.–Oct.	100–125	no	overwinters very well	no	+[2]	–
Legumes	April–June	species dependent	yes	most overwinter	usually not	0 to +++	0 to +++
Non-legume broadleaves							
Oilseed radish	Mid-Aug.–early Sept.	10–14	no[3]	killed by heavy frost	yes	0	0
Buckwheat	June–Aug.	50–60	no	killed by first frost	yes	+++	0

NEMATODE RATING CODES: (–) poor or non-host (+) ability to host (0) some cultivars are non-hosts

[1] Varietal differences in cover crop species may affect nematode reaction.

[2] Rye — whole season rating would be higher (+++)

[3] Oilseed does not fix nitrogen from the air, but is a strong accumulator of nitrogen from soil and manure applications.

be used on grass cover crops to reduce weeds. Avoid seed set of the cover crop and any weed escapes.

Soil Fumigation

Soil fumigation can control nematodes and certain soil-borne diseases. Nematodes are most likely to cause problems on sandier soils. Soils should be sampled the year before planting strawberries to determine nematode levels (see the section on *Monitoring* on page 48). A population of 500 root lesion nematodes per kg of soil may cause strawberry plants to be stunted and unhealthy. If fumigation is required, it should be done in the fall of the year before planting, usually in September or early October, when the soil is warmer than 4°C at 15 cm depth. This allows the fumigant to act and disappear from the soil so strawberries can be planted safely in the spring. Fumigation in spring, although effective, is not recommended, because planting must then be delayed for several weeks.

Fumigation may be justified where rotations cannot be followed, or where there is a history of root rot or verticillium wilt, and other sites are not available.

The soil should be worked several weeks before fumigation to a depth of 20–25 cm. It should be free of undecomposed crop residues, be uniformly moist and in good seedbed condition. The fumigant is injected 15–20 cm into the soil, and the soil is immediately packed or watered to prevent loss of the chemical. Soil fumigation can be performed by custom operators.

Some pre-plant nematicides may be mixed with water and injected, or applied in irrigation water. Here, the deeper the water penetrates the soil after application, the more effective the nematicide will be.

The soil should be left undisturbed for at least 2 weeks following fumigation in the fall. A cover crop can be grown to prevent soil erosion over winter. Crops such as Italian rye grass at 22 kg/ha or winter rye, spring wheat or oats at 125 kg/ha can be used. Wait at least 1 or 2 weeks after fumigation before aerating the soil to plant the cover crop.

Strip fumigation can be used with some systems of planting to reduce the cost. If strawberries are to be grown on a hill or narrow, raised row, the soil can be fumigated in strips and the fumigated strip used to form the hill or raised ridge. The fumigants should be applied 30–45 cm deep to allow for the soil movement when the bed is made. Strip fumigation is not recommended for matted-row or solid-bed planting, because the strips between the rows are not wide enough to prevent nematode populations from building up on the runner plants that root there.

Refer to OMAFRA Publication 360, *Fruit Production Recommendations*, for recommended fumigants and notes. Be sure to follow the manufacturers' instructions closely.

Nematode populations may be reduced below threshold levels without using fumigants. Various soil management practices and nematode-suppressing cover crops can reduce nematode populations. These methods do not control nematodes as rapidly as soil fumigation and may require more than one growing season to effectively reduce nematode populations.

Planting

Preparation for Planting

Source of Plants

Healthy plants must be used to start a new planting. Strawberry plants are susceptible to many virus diseases that reduce the vigour and yields of all varieties. Plants do not perform reliably when produced where adequate precautions are not taken to control virus spread.

Several nurserymen in Ontario propagate strawberry plants from virus-indexed stock according to the guidelines of the Ontario Strawberry Plant Propagation Program. This program is designed to provide Ontario strawberry growers with a reliable supply of high-quality, essentially virus-free, Ontario-grown planting stock and to control red stele, verticillium wilt, black root rot, cyclamen mites, nematodes and several other pests. A list of plant growers who have had their fields inspected and appear to have followed the guidelines of the program is available each year from:

- the OMAFRA Web site at www.gov.on.ca/omafra/english/crops/resources/sources.html
- the Ontario Berry Growers Association, c/o Talisman Farm, RR#4, Uxbridge, Ontario, L9P 1R4

Copies of the guidelines of the program are also available.

Plants grown according to the Ontario Strawberry Plant Propagation Guidelines or a similar program in another province or state should be used each year when starting a new planting. Ontario growers who have used such plants have successfully maintained high yields in plantings kept for three or more crops. If possible, new plants should be set 300 m or more from plants not produced under the program to reduce virus spread into the new planting.

The initial health of the planting stock is only one factor that contributes to successful fruit production. Plants cannot be expected to grow well if they have not been stored or handled correctly or if they are subjected to adverse conditions after planting.

Weed Management

Control perennial weeds the year before planting. Annual broadleaf weeds and grasses may be controlled for 4–6 weeks after planting if a residual herbicide is used. See OMAFRA Publication 75, *Guide To Weed Control*, for recommendations.

Soil Fertility

Fertilizers applied in the spring before planting should be drilled in or worked in several days before planting. Nitrogen (N) is required for successful plant establishment. Apply 50 kg of N/ha before planting or as a side dressing 2–3 weeks after planting. Adjust nitrogen rates proportionately if manure was applied (see Table 3–3, *Average Amounts of Available Nutrients for Different Types of Manure*, on page 15).

The amount of phosphorous and potassium to apply before planting can best be determined by a soil test (see Table 3–1, *Phosphorous and Potassium Requirements for Strawberries*, on page 12). Avoid excessive levels of phosphorous as these may induce zinc deficiency, especially on sandy soils. Potassium leaches rapidly on coarse sandy soils. For this reason it should be applied in the spring before planting, rather than the year before. Side-dressing potassium is not usually recommended.

Starter fertilizers high in phosphorus, such as 10-52-10 or 10-40-10, are sometimes added to the transplant water at the time of planting to assist in the establishment of the roots and crown. Follow the manufacturer's instructions. These starter solutions provide readily available nutrients that promote rapid plant growth. Many growers find that water alone is sufficient if the soil is fertile and temperatures are warm. If soils are cold, however, phosphorous availability in the soil is significantly reduced, and starter fertilizers are important.

Soil Condition

Before planting, work the soil to get a deep and reasonably loose "planting bed." If the soil is too loose, such as from deep rototilling, it will be hard to set plants at the proper depth when planting. Such soils may need to be rolled, culti-packed or allowed to settle for a few days before planting. If soils are worked excessively, organic matter and soil structure are quickly broken down.

Matted-Row Planting System

This is the most common planting system for commercial strawberry production in Ontario. Plants are set out in rows, and runners from these plants are trained into the rows. A spaced matted row — where the number of plants per square metre is controlled — is much better than a matted row where all runners are permitted to root. Having too many plants per square metre is often a problem in matted rows.

In a typical matted-row planting, rows are spaced 106–120 cm apart and rows are kept about 45 cm wide. Research has shown, however, that for a given number of fruiting plants per acre, yields increase as the number of

TABLE 3–3.
Average Amounts of Available Nutrients for Different Types of Manure

Nutrient values based on average analysis results for over 700 samples. [1]

Manure	Average Dry Matter	Available Nitrogen[2] Spring – 1 day	Available Nitrogen[3] Spring – not incorp.	Available P_2O_5 [4]	Available K_2O [5]
	kg/1,000 L (lb/1,000 gal)				
Liquid dairy	6.5%	1.6 (16)	0.6 (6)	0.7 (7)	3 (30)
Liquid hog	3.6%	2.6 (26)	0.7 (7)	1.1 (11)	2 (20)
Liquid poultry	8.0%	6.1 (61)	1.7 (17)	2.5 (25)	3.4 (34)
Liquid biosolids (sludge)[6]	4.4%	1.2 (12)	0.6 (6)	1.3 (13)	0.2 (2)
	kg/tonne (lb/ton)				
Solid biosolids	36%	1.5 (3)	0.75 (1.5)	11 (22)	0 (0)
Solid poultry	49%	11.5 (21)	6 (12)	9 (18)	12.5 (25)
Solid dairy	20%	1.5 (3)	0.7 (1.4)	1.5 (3)	5.5 (11)
Solid beef	27%	1.5 (3)	0.75 (1.5)	1.5 (3)	7 (14)

[1] There are large variations between different manures, so a manure analysis is your best guide to nutrient availability.
[2] Nitrogen based on spring application, incorporated within 24 hours.
[3] Nitrogen based on spring application, not incorporated (i.e., on soil surface for over 7 days).
[4] Phosphate from manure or biosolids is assumed to be 40% as available as that in manufactured fertilizer in the year of application.
[5] Potash from manure or biosolids is assumed to be 90% as available as that in manufactured fertilizer in the year of application.
[6] For biosolids (e.g., sewage sludge), you must get a certificate of approval from your local MOE office. This can take up to 6 months.

row edges increases. In other words, a planting with more, narrow rows is more productive than a planting with fewer, wide rows. Some growers have been successful with row spacings of 90 cm between centres. Equipment size and the slope of the land are two important considerations when determining row width (use wider spacings for steeper slopes). Some growers feel that PYO customers find picking more comfortable at wider row spacings.

If row centres are close together (90–100 cm), rows should be kept narrow (30–45 cm wide). For wider spacings (120–130 cm from centre to centre), rows can be allowed to grow 50–75 cm wide. Studies at the Horticultural Institute of Ontario (HRIO) have indicated that for rows spaced 120 cm apart, yields increased as the width of the plant area increased up to 70 cm wide.

With more rows, more plants are required for planting, and more runners need to be removed so plant areas do not get too dense and wide.

The recommended distance between plants in the row varies with variety and soil conditions. As a general guide, most varieties can be planted 40–60 cm apart. Use the wider spacing for vigorous varieties; less vigorous varieties should be planted more closely in the row. If vigorous varieties are planted too closely, too many runner plants will crowd the row. On the other hand, if plants are spaced too far apart, less productive, late-formed runner plants will be needed to fill the row.

See the section on *Thinning and Spacing* on page 17 for thinning and spacing instructions.

Planting Considerations

Number of Plants per Hectare

The number of plants needed to plant a hectare can be determined as follows. Multiply the distance between rows, for example 120 cm (1.2 m), by the distance between plants in a row, for example, 60 cm (.6 m). Thus, 1.2 m x 0.6 m = 0.72 square metres. Divide 0.72 into 10,000, which is the number of square metres per hectare. The result, 13,889, is the number of plants per hectare needed at this spacing.

Time of Planting

Spring planting is recommended. Plant as soon as the land can be prepared – usually late April or early May (Plate 3). This permits the plants to become established before the onset of hot, dry weather. Plants that are estabished early start producing runners early. This is desired because runner plants that form early have the highest yields.

Fall planting is not recommended. At normal planting distances for matted rows, yields in the following summer are too low to justify picking. If large numbers of plants are set out in late summer or early fall, a fair yield can be obtained the following summer, however, plants are not normally available from nurserymen until November.

Dormant Plants

It is important to use dormant plants (Plate 4). These are plants that have been dug early in the spring before root growth has started. Plants are then cold-stored until set out. Plants that have started to grow before being dug up don't grow as well as dormant plants because they have used up some of their stored food reserves.

Some plants are dug in late November and stored over winter at about –2°C in polyethylene bags in boxes. The polyethylene prevents excessive drying of the plants. Plants can be stored well for 6 months or more under these conditions. Do not be concerned if some of the plants that were dug in the fall appear dry; as long as the roots and crowns are free of storage rot and are not limp or shrivelled, they should grow well.

Handling the Plants

Dormant plants should be obtained as close to planting time as possible. If planting is delayed, the plants can be kept for 2 or 3 days in a cool, shaded place. For longer delays, keep plants in cold storage at about 0°C. Plants should not be set out directly from the cooler especially if they are frozen. Plants that had begun to grow before being dug up should not be stored.

Plants should not be allowed to heat up or dry out while being stored. If they are in plastic bags, there is little danger of them drying out. If the plants are not in plastic bags, the roots should be kept moist, but not wet. Plants should not be left in water.

During planting, do not expose plants to the sun or wind for any length of time. Some growers wet the plants just before planting to keep roots from drying out during planting. Keep plastic bags of plants out of direct sunlight, because the plants inside can get very hot. Planting on a cool, cloudy, still day is preferable to planting on a hot, sunny or windy day.

Depth of Planting

Plants should be set so that the midpoint of the crown is at the level of the soil surface (Plate 5). If set too deep, the crown may be damaged or rot, and the production of runners is delayed and reduced. If set too shallow, the crown and tops of the roots dry out.

Setting the Plants

Transplanting machines such as those used for tobacco or vegetables are suitable for setting strawberries. As many as 25,000 plants can be set in a day by experienced workers using a one-row planter. Water or a starter solution can be applied with a planting machine during planting. Use cleaned plants and place them in orderly bunches with the roots all in one direction. Two problems often occur with machine planting: the furrow is not deep enough to let the roots go down 10 to 15 cm, and the soil is not firmed well around the plants. Proper soil preparation overcomes these problems. Someone should follow the planter to check planting depth, to make sure the soil is packed well around the plants and to fill any missed places in the row. Keep tractor exhaust fumes away from the people behind the planter.

New plantings of less than 0.5 ha can be planted by hand by two people working together using a spade or shovel.

Irrigation immediately following planting is essential, unless it rains.

Care of the Young Planting

In the first season, every effort should be made to get a good row of early-established vigorous runner plants. This signifcantly affects the size of the next year's crop.

Fertilization

If nitrogen (N) was not applied prior to planting, apply 50 kg N/ha as a side dressing 2–3 weeks after planting. An additional 25–35 kg N/ha should be applied in mid-August to further invigorate plants as they initiate fruit buds for the next year's crop. Adjust rates if manure has been applied (see Table 3–3, *Average Amounts of Available Nutrients for Different Types of Manure,* on page 15).

Samples of mature strawberry leaves can be analyzed for major nutrients and micronutrients. A leaf analysis will often provide better information than a soil test. Leaf analysis samples can be collected after plants are established, but before August 20. Sampling instructions and a list of accredited laboratories are available on the OMAFRA Web site at www.gov.on.ca/omafra/english/crops. Optimum ranges for concentrations of nutrients in strawberry leaves are given in Table 3–4, *Optimum Ranges of Nutrient Concentrations in Strawberry Leaves,* on page 17.

Cultivation

Cultivation is needed to train runners and prevent crusting of the soil, which delays runner-plant rooting. Shallow cultivation often improves weed control obtained from herbicides. Cultivate soon after planting to smooth the soil around the plants and remove wheel marks from planting machinery. Repeat the cultivation only as often as needed to control the weeds, to keep the soil loose for the runner

TABLE 3–4.
Optimum Ranges of Nutrient Concentrations in Strawberry Leaves

(Recently matured leaves, petioles removed, collected prior to July 1, in fruiting fields and prior to August 20, in non-fruiting fields.)

% dry weight					ppm			
N	P	K	Ca	Mg	Mn	Fe	Zn	B
2.0–3.0	.20–.50	1.5–2.5	.5–1.5	.25–.5	20–200	25–200	15–100	20–60

plants to root and to train unrooted runners into the row. Shallow cultivation will reduce damage to strawberry roots.

Handhoeing for weed control should be shallow and should move toward the plants (without burying the crowns) rather than away from it. To fill in gaps, combine runner spacing with handhoeing.

Mechanical hoes are available for cultivating between plants in the row as well as between rows. These hoes may be useful in the early part of the first growing season. However, once runners are rooting, this equipment should not be used for cultivating.

Always cultivate in the same direction in a row so that runners already trained into position will not be disturbed. Do not bunch runners into a dense, narrow row with the cultivator. Allow the rows to get about 5 cm wider with each cultivation. This will help provide good, in-row plant spacing. After the row has grown to the desired width, cut off any runners trailing out between rows. They can be cut with coulters, rototillers, etc.

Weed Management

Herbicides recommended for use in newly planted strawberries are listed in OMAFRA Publication 75, *Guide to Weed Control.* A pre-plant, incorporated herbicide should provide weed control for about 6 weeks. After plants are established, about 4–6 weeks after planting, another application of herbicide can be made. Strawberry plants can be very sensitive to herbicides while runners are forming and taking root. During this time, certain herbicides should not be applied. Cultivation to train runners can also be timed to help control weeds. Handhoeing will be necessary to control weeds within the row.

By late summer or early autumn, sufficient numbers of runners should have rooted and the strawberry row filled in. At this time, low rates of certain herbicides can be applied for control of germinating winter annuals. Herbicides may also be applied just prior to mulching.

OMAFRA Publication 75, *Guide to Weed Control,* is revised annually and should be consulted for the most current herbicide recommendations.

Herbicides are applied to strawberries using boom sprayers, in spray volumes of 150–300 l/ha and operating pressures of 135–345 kPa (check the herbicide label for the most appropriate spray volume). Nozzles with flat fan tips should be used for herbicide application because they deliver a uniform pattern under low pressures and will minimize drift. Cone nozzles and high pressures, which are used for the application of fungicides and insecticides, are not appropriate for herbicide sprays. A separate sprayer used only for herbicides should be used to avoid contamination.

Geese for Weeding

Geese were once widely used in strawberry plantings for weed control. This method of weed control may still be practical in smaller or organic plantings. Geese will not eat strawberry plants unless desperate for food. Geese do not eat certain weeds, such as round-leaved mallow, smartweed and docks. Use geese only in non-bearing strawberry plantings, as fecal and other bacteria could contaminate the fruit.

Blossom Removal

Removing flower stalks on newly set plants will result in the plant sending out more runners earlier. Wait until the bloom develops enough that whole clusters rather than individual flowers can be cut or pinched off. Most of the clusters can be removed at one time.

Thinning and Spacing

The number of plants per square metre of row greatly affects yield and berry size. Too many plants will lower yield and berry size because of crowding and competition for water, sunlight, air and nutrients. If fruit size drops rapidly after the first picking or two, it is possible that the plants are too densely spaced. Poor pollination is likely to occur in crowded rows. Fruit rots can be a problem in dense rows, because the foliage is wet longer, and humidity around the plants stays high, providing suitable conditions for plants to become infected with various diseases. Thorough spray coverage is also more difficult to achieve when rows are wide.

Generally, having about 40 plants per square metre (6–8 plants/sq ft) that are well rooted by early August is best. This means a spacing of about 15 cm between plants. Runners produced after the desired spacing has been reached act only as weeds and should be removed. When too few runners are formed, yields will be low.

Choose an appropriate planting distance between plants in the row to obtain the optimum plant spacing. If rows tend to be too thick, try a wider spacing. Do not set plants so far apart that late-formed plants are needed to fill in the row. Use a hoe to swing unrooted runners into any large gaps in the row. After the desired row width is formed, cut off runners that occur between rows. Use a rolling coulter in front of the cultivator, rototiller, etc. Side-delivery rakes and windrow turners can be used to rake unrooted runners into the alleys between rows, where they can be cut off.

Mulching

Importance of Mulching

Fall mulching to provide protection from winter injury is recommended (Plate 6), especially where snow cover is unreliable. Strawberry plants can generally withstand crown temperatures of –5°C in early fall and –15°C throughout the winter. Prolonged conditions below these temperatures can result in significant winter injury.

The symptoms of winter injury can be seen clearly when a crown is cut lengthwise in spring (Plate 7). The internal tissue will show browning, which can extend into the roots near the crown. Because of the nature of the crown and root system, the plant can tolerate some injury. However, the injury weakens the plant, and if there is much injury, the plant does not grow or yield well.

Benefit of Mulching

Straw mulch applied over strawberry plants in late fall will help prevent injury to crowns and roots due to low temperatures. It will keep soil temperatures more uniform during the winter and prevent the freezing and thawing of the soil that tends to lift plants out of the ground and cause roots to break. Mulch will help prevent plant desiccation due to cold, dry winds. By delaying mulch removal in the spring, bloom can be delayed several days, and the risk of frost injury to developing blooms may be less. When placed between rows in the spring, the mulch depresses weed growth, conserves soil moisture, reduces soil compaction, keeps soil from splashing on berries during rains or irrigation, reduces the spread of soil-borne disease and makes picking more pleasant.

Some growers in Southern Ontario do not mulch plants over winter, because they find the crop ripens earlier on unmulched plants. The high price of early berries can offset some yield loss that might result from winter injury. The presence of a straw mulch between the rows can also affect the degree of frost protection required during bloom. An unmulched planting will be somewhat warmer than a mulched planting on frosty nights, because bare soil will hold more heat than straw. However, the potential for winter injury is always greater in an unmulched planting.

Where mulch is not applied for protection from winter injury, it should be applied just before fruit set, to keep berries clean from splashing soil.

Mulching Materials

A good mulch material should be free of weed seeds, coarse enough that it does not pack down and cause smothering, heavy enough that it does not blow away and fairly inexpensive. Wheat straw is favoured, but oat or rye straw and marsh hay are also suitable. Straw often contains grain seeds that grow the following spring and act as weeds. Herbicides, applied immediately before mulching, help control this grain. Consult OMAFRA Publication 75, *Guide to Weed Control,* for details.

Mulching material should be dry and not frozen, so it can be spread easily. The amount to use will vary with the material, but wheat straw should be 5–8 cm thick when settled. This requires about 5–8 tonnes/ha (300–400 small, square bales/ha).

In northern areas, a clear layer of plastic can be placed over the plants before the straw mulch is applied. This use of plastic can help if temperatures drop sharply before mulching. The plastic also warms the soil in the spring, bringing blossoms earlier.

Times of Application

Cover plants after they have been hardened by several sharp, frosty nights, but before temperatures drop much below –7°C. In general, mulching is done in November. The mulch is best applied if the ground is frozen, as this prevents the equipment from making deep ruts and packing the soil. Snow or light rain occurring just after the mulch is applied will settle the mulch into place and keep it from blowing away.

In eastern and northern Ontario, an early snowfall may occur before mulch is applied, with no harmful effects. Straw should then be applied over the snow, when possible.

Application Equipment

Straw spreaders are commercially available or can be custom made. Some growers have modified forage wagons and use loose straw or straw from large bales to mulch two rows at a time.

Mulch Removal

Remove mulch in early spring, after the danger of severe frost has passed but before much new plant growth occurs under the mulch. Plants respond best if the mulch is removed when soils reach 4°C. When plants start to grow under the mulch, the new leaves have a slightly yellow colour. Some growth can occur without causing any problem. However, if much growth occurs, the new leaves will be very pale and spindly, yield potential is reduced and crowns can be easily damaged during the mulch removal process. Delay in removing the mulch results in some delay in blossoming and fruit ripening. In some areas, this may help avoid late spring frosts.

When mulch is removed, it can be raked into the pathways between the rows. Windrow-turning equipment and side-delivery rakes can then be used for mulch removal.

Care in the Harvesting Years

Pollination

Nearly all blossoms of the strawberry varieties in Ontario can produce pollen and develop into berries. Blossoms are pollinated either with their own pollen or with pollen from flowers of any variety. Usually, each blossom produces large amounts of pollen, although some of the first blooms to open in the spring may lack functional stamens (the flower parts that produce pollen).

Berry size and shape are greatly influenced by the number of developing seeds located on the surface of the berry. Without the developing seeds, there is no swelling of the berry. If a group of seeds in one area of the berry fails to develop, that part does not swell properly and a misshapen berry results. This condition is often called "catfacing" or "button berry." Misshapen berries can be caused by incomplete pollination, high temperatures and drying winds during bloom, frost injury to blossoms, tarnished plant bug injury or any other factor that prevents seed development.

While strawberries can set some fruits without insects, experience shows that larger and better-shaped berries result when bees and other insect pollinators are plentiful. Strawberry blossoms are very attractive to bees, and the use of honey bees is recommended to ensure good pollination (Plate 8).

Provide two colonies of honey bees per hectare throughout the bloom period. Insecticides should be avoided during this time, but if insect control is necessary for tarnished plant bug, take appropriate precautions. See OMAFRA Publication 360, *Fruit Production Recommendations,* for information on the toxicity of pesticides to bees, and apply only those that are least toxic, preferably in the very early morning or evening.

Fertilization

Determine fertilizer requirements using a soil test or leaf samples. Soil tests can be conducted annually to determine if potassium and phosphorous are needed in the cropping years. Table 3–1, *Phosphorous and Potassium Requirements for Strawberries,* on page 12, provides recommended rates of phosphorous and potassium based on soil test results.

Samples of mature leaves can be analyzed for major nutrients and micronutrients. For perennial crops such as strawberries, a leaf analysis will often provide better information about micronutrients than a soil test. Leaf analysis samples from mature plants should be collected just prior to harvest or after renovation, but before August 20. Collect recently matured leaf blades (a leaf blade is made up of three leaflets) with the petiole removed. Sampling instructions and a list of accredited laboratories are available on the OMAFRA Web site at www.gov.on.ca/omafra/english/crops. Information on interpreting a leaf analysis is found in Table 3–4, *Optimum Ranges of Nutrient Concentrations in Strawberry Leaves,* on page 17.

Two key times for the application of fertilizer to strawberries are following renovation and late summer/early fall.

After strawberries have been harvested and plants have been mowed, apply 50 kg N/ha. This nutrition is needed to keep plants actively growing and prevent the natural tendency of the plant to become dormant after harvest. If soil tests or leaf analyses indicate that potassium or phosphorus are required, apply these with the nitrogen at renovation.

In the late summer and early fall, flower buds are formed for the next year's crop. A second application of 25–35 kg N/ha should be applied in mid-August to provide adequate nitrogen for flower bud formation.

Avoid spring applications of nitrogen in most situations. Excess nitrogen before harvest will promote vigorous top growth, encourage fruit rots, soften berries and reduce post-harvest quality and shelf-life. Maturity will be delayed by a day or two where nitrogen is applied before harvest. There are only a few situations where nitrogen application may be beneficial before harvest. Older plantings on sandy soils or fields suspected of having winter injury may benefit from a very light spring application of nitrogen. Where these conditions exist, the nitrogen should be applied immediately after mulch removal and only at very low rates (no more than 10 kg/ha). Growers should practice applying nitrogen in spring on a portion of their plantings before making it a general practice.

Do not apply nitrogen, phosphorus or potassium as foliar applications, as the leaves only absorb very small amounts of these nutrients.

In contrast, nutrients such as boron, magnesium and zinc can be applied effectively through the leaves to correct deficiencies. Leaf analysis will determine the levels of these nutrients more accurately than soil analysis; the optimum ranges are given in Table 3–4, *Optimum Ranges of Nutrient Concentrations in Strawberry Leaves,* on page 17.

Fertigation

Soluble fertilizers can be applied through sprinkler irrigation systems. This is a convenient and effective way of applying fertilizers, especially nitrogen, after planting. Ammonium nitrate, ammonium sulphate, calcium nitrate, urea and soluble potassium fertilizers can be applied effectively by irrigation. Even coverage by the irrigation system is needed. Soluble fertilizers can also be added through trickle or drip irrigation systems.

Harvesting

June-bearing strawberries are ready for harvest approximately 20–30 days after bloom, depending on temperature, cultivar, nitrogen levels, etc. The first, "king" berries ripen about 30 days after first bloom and the main crop berries ripen 20–23 days after they bloom.

Hand Harvest

Fifteen to twenty-five people are needed to harvest 1 ha, depending on their experience, the size of the crop and the rate at which the strawberries are ripening. For the fresh market, berries are generally picked every 2–3 days. In hot weather, it may be necessary to pick every day. To retain good pickers, there must be a good quantity of ripe berries at each harvest date. Usually, processing berries can be picked once a week unless they ripen very rapidly. Berries generally should be picked when they are completely or nearly red. Partly coloured berries will colour after picking, but will not have full flavour. For shipping to distant locations or long periods in storage, it may be necessary to consider picking partly coloured berries.

Give pickers proper instruction and careful supervision to ensure a good-quality pack. Instruct pickers to pick all ripe berries. Missed berries will be overripe and perhaps rotten by the next picking. Overripe or rotten berries should not be placed in the box with sound berries, but should be removed from the row and preferably from the field.

Berries for the fresh market should be picked by using the thumb and forefinger to grasp the stem just above the berry. Pull with a slight twist to break the stem about 1 cm from the berry. Let the berry roll into the palm of the hand and pick a second berry as before. Pick with both hands. Hold only two or three berries in the hand at one time to avoid crushing. Gently place picked berries into the boxes. Berries for some processing uses can be picked with less care. Processing berries are sometimes picked with the hulls (calyces) off.

Pickers are usually paid by the box. A simple way to keep a record of each picker's earnings is to supply the picker with a card that is punched for each full box or carrier.

Mechanical Harvesting

Machines that remove all the crop at one time are available to harvest strawberries for processing (Plate 9). They are not suitable for picking berries for fresh-market sale. The harvesting machine cuts the plant and berry clusters about 1.5 cm above the ground, then the berry clusters are separated from the leaves. Clusters are transported to the processing plant in bulk containers. The fruit must be separated from the cluster and decapped for all processing uses except juice and puree. Machines that decluster and decap the berries are also available. Decappers hold the berry stalk between two counter-rotating rollers that move the berry across a sharp blade, cutting it just above the calyx. The decapper only works effectively on varieties with a strong berry stalk, e.g., Midway and Scotland. Many common varieties have a weak berry stalk that breaks just below the calyx. If this happens, the fruit rolls away without the calyx being removed.

Containers

Choose a container that meets the needs of your intended market. The standard strawberry container is a cardboard master containing eight individual cardboard boxes. Variations include 6-qt masters, 12-pt masters, 4-L baskets and plastic clamshell boxes. For the fresh market, strawberries should be picked into the containers they will be sold in, generally quart boxes. Sorting fresh market berries after picking increases bruising and costs. The pickers are supplied with quart boxes in a cardboard shipping master or carriers (flat trays with handles) that hold the individual quart boxes. When filled, the carriers or masters are taken to the packing shelter, where they can be checked for quality and fullness. Berries for processing can be picked into shallow, plastic, reusable trays.

Post-Harvest Handling

Field Packing Shelter

Provide a shaded area or wagon in the field for harvested berries until they can be taken to cold storage. The shelter keeps berries from heating up in the sun and also provides shade for the people receiving the berries from the pickers. Pickers should not have to carry boxes long distances. Berries should be moved to cooling facilities within 1/2 hour after picking.

Cooling and Storage

Strawberries lose quality rapidly and continuously after harvest. This deterioration occurs because of normal chemical changes that take place in living berries, and because of decay-causing organisms growing on the berries. Prompt, rapid, uniform cooling after harvest is critical to stop berries deteriorating and to increase their shelf life. It also reduces water loss from the berries, stops their shrinking, reduces the blemishes on berries and slows the growth and spread of micro-organisms. Berries must be cooled rapidly and stored cool, even at the retail level.

Cool berries below 4°C, and preferably to 0°C, within 2 hours of harvesting and keep them cool. Delays between picking and cooling lower quality and shorten the shelf life of berries. Berries deteriorate as much in 1 hour at 20°C as they would in 4–8 hours at 0°C. Berries exposed to direct sunlight can be warmer than the temperature of the surrounding air. They can exceed 38°C by 10 AM. Even if berries are fairly cool when picked and are kept in the shade, they can warm up as they respire.

Containers of harvested berries placed in a cold storage do not cool rapidly (Plate 10). In tests at the Horticultural Research Institute of Ontario, a single stack of five masters placed in cold storage at 0°C took 6 hours to cool from 21°C to 4°C and a further 10 hours to reach 0°C. Cooling is even slower when masters or skids of masters are stacked close together. Cold air must be pulled around the berries to cool them to below 4°C in less than 2 hours. The process is called forced-air cooling. Refrigerated air is pulled through containers and around the berries because of a vacuum created by high-capacity fans (Plate 11). The refrigeration requirements for forced air cooling are higher, because the heat is removed more rapidly.

After cooling, hold berries at temperatures as close to 0°C as is practical, keeping the relative humidity above 90%. This practice ensures that the berries do not dry out or lose weight or attractiveness. Sound berries that are cooled rapidly can be stored at 0°C for over 5 days depending on the variety. Water condenses on cooled berries brought into warmer temperatures. This does not harm them, but can be prevented by covering the skid of berries with plastic.

Further information on cooling is contained in the OMAFRA Factsheets *Sizing and Laying Out a Short-Term (Summer) Refrigerated Storage for Fruits and Vegetables*, Order #92-124, and *Tunnel Forced-Air Coolers for Fresh Fruits and Vegetables*, Order #98-031.

Renovation

Producing matted-row strawberries profitably depends on the production of several crops from the same planting. Nearly all growers in Ontario keep strawberry plantings for two or three crops. Yields in the second cropping year are usually equal to or even higher than yields in the first cropping year, but usually decline thereafter. Plantings may produce crops for more than 4 years, if they are well cared for.

Renovation prepares the planting for a subsequent crop. Renovation practices encourage the growth of healthy, vigorous strawberry plants. Renovation reduces stresses due to leaf diseases, poor weed control, soil compaction, poor root growth and inadequate fertility (Plate 12).

A healthy planting can usually be renovated more cheaply than a new one can be established. In general, plantings with more than a 70% plant stand can be successfully renovated. However, renovation does not correct winter injury or control soil-borne diseases and perennial weeds. If these are a problem on more than one-third of the planting, it may be more economical to replant than to renovate.

Steps in Renovation

Renovation involves a series of steps: first the herbicides and fertilizers are applied, then the planting is mowed, the rows narrowed and thinned, and the conditions for plant growth are improved. The land can also be subsoiled if required. The order of these steps may vary depending on the individual circumstances. Begin as soon as harvest is complete.

Weed Management

A 2,4-D-type herbicide to control broadleaved weeds may be applied just before or shortly after the strawberry foliage is mowed. Usually the herbicide is applied 2–5 days prior to mowing, so that the weeds absorb most of it. If weeds are small and hidden beneath strawberry foliage, control may be improved if the herbicide is applied after the planting is mowed.

A residual herbicide may be applied after the planting has been mowed and cultivated to kill germinating weed seedlings for the rest of the growing season. Grass herbicides may also be applied when grasses are actively growing. Irrigate before the herbicide is applied to encourage weeds to germinate and cause existing weeds to grow. This improves the effectiveness of the herbicide. Irrigate after a pre-emergence herbicide has been applied to help incorporate the herbicide and wash it off the strawberry leaves.

For more information on weed control, consult OMAFRA Publication 75, *Guide to Weed Control.*

Fertilization

Apply 50 kg N/ha. If potassium and phosphorous or other nutrients are required, apply these with the nitrogen. See the section on *Fertilization* on page 19 for more information.

Mowing

Mow the tops of strawberry plants approximately 2–5 cm above the crown, taking great care not to damage the crown. This helps to control mites and leaf diseases, encourages new growth, removes runners as well as leaves and reduces competition between plants in the row. Research has shown repeatedly that when the leaves are removed at this time, yield is increased the following season.

Mowing should take place immediately after harvest. The plants need time to re-grow by mid-August, when fruit bud initiation begins. Plantings that are renovated later have fewer fruit the following season.

In northern Ontario, growers may choose not to mow off foliage after harvest. Because the harvest ends later and frost comes earlier in the North, there may not be enough time for strawberries to re-grow and initiate fruit buds after mowing.

Narrowing Rows

Narrow the rows to remove runner plants that have formed during the harvest period and maintain optimum plant density. Plants do not generally produce runners much after mowing, so rows should be narrowed only to the width desired for picking or a few centimetres less. If row centres are close together (90–100 cm, between centres), then rows should be kept narrow (30–45 cm wide). If row spacings are wider (120–130 cm between centres), rows can be allowed to grow wider (50–75 cm wide). Wider rows may create more favourable conditions in the centre of the row for fruit diseases. To thin wide rows that have become dense in the centre, remove a narrow strip of plants from the centre of the row, using a cultivator tooth.

Rows can be narrowed either mechanically or with herbicide. Many growers have adapted large rototillers to straddle the strawberry row, by removing the centre blades (Plate 13). Multi-row rototillers are also available. When the rows are narrowed mechanically, the soil is loosened in the rooting zone. The old straw and leaves are worked into the soil, which has the added benefit of reducing the disease inoculum.

Sometimes herbicides are applied to narrow the rows. Gramoxone can be used to kill strawberry plants and weeds between the rows. Shields on the sprayer are adjusted to the desired row width to protect plants in the row from the spray. One disadvantage to using herbicides to narrow the rows is that the disease inoculum is not reduced because the old straw and leaves are not worked into the soil.

For more information on application and rates, consult the product label. See the section on *Special Methods of Weed Control – Stale Seedbed and Inter-Row Weeding* in OMAFRA Publication 75, *Guide to Weed Control.*

Plant Thinning

Plants may need to be thinned to maintain the optimum plant spacing. Plants should be thinned 15–22 cm apart. Extensive hand thinning is not practical. After the rows have been mown, rake unrooted runners and weakly rooted plants into the alleys where they can be destroyed when rows are narrowed. This will help prevent rows from becoming too thick. If there are thin areas in the rows, runners should be trained into them before rows are narrowed.

Improving Root Growth

The rooting zone of a strawberry plant moves upwards as the plant grows. As new leaves develop at the top of the plant, older leaves near the bottom die. New roots will develop through the old leaf bases if soil is available for them to grow into. To encourage new roots to grow from the crowns, cover them with 1 cm of soil. If they are not covered with soil, the crown becomes an elongated, barren stem, susceptible to winter injury and unable to produce new roots.

Soil can be added over the top of the plants at renovation, with a cultivator or rototiller. The soil between the rows should be tilled once or twice using a shield to keep this soil and mulch material off the crowns. Once the weeds, leaves and mulch are well worked into the soil and broken down, up to a half-inch of soil can be added to the base of the crowns by rototilling with the shields off. If the soil is very dry, irrigation is required to encourage new roots to form.

Subsoiling

The planting should be subsoiled between the rows if the soil has become compacted or hard pans have formed. Subsoiling to a depth of 25 cm or more helps to improve soil drainage. Do not subsoil while soils are still wet, or compaction problems will be increased.

Care After Renovation

Following renovation, the planting is handled like a first-year planting. Little cultivation is needed. New runners are usually not needed, so those that trail into the alleys should be cut off. Irrigation, a late-August nitrogen application and a winter mulch are just as important as for first-year plantings.

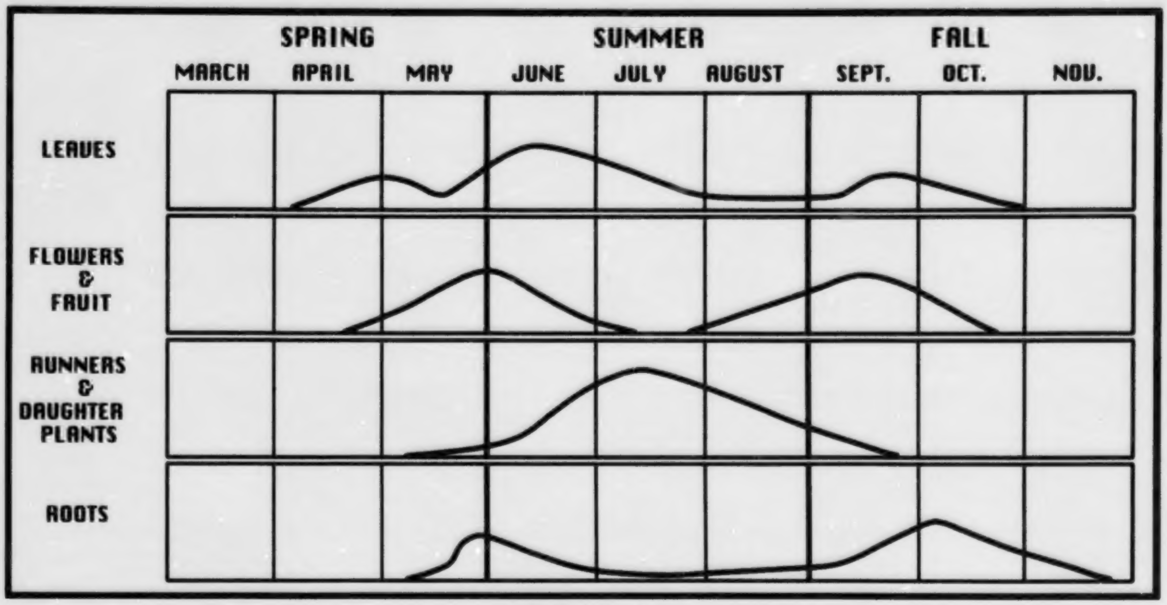


FIGURE 3–2.
Strawberry Plant's Water Requirement Through a Typical Growing Season
Peaks on the graph indicate periods when water is particularly important for the plant parts listed on the left.
Source: *Best Management Practices: Horticultural Crops*, Agriculture and Agrifood Canada and OMAFRA, 1993

Irrigation and Frost Protection

Irrigation

Benefits of Irrigation

Additional water applied to strawberries at times when the plant is under stress will help increase plant growth and yield in many ways. It encourages plants to establish rapidly in new plantings, protects blossoms from spring frosts, improves fruit set through evaporative cooling and increases fruit size. It creates favourable soil conditions to enable runners to root, encourages vigorous regrowth of the plants at renovation and helps incorporate herbicides. In late August to September, adequate soil moisture is essential for good fruit bud initiation.

Strawberries are shallow-rooted and need the most moisture when rainfall amounts are the most unpredictable (see Figure 3–2, *Strawberry Plant's Water Requirement Through a Typical Growing Season,* above). Strawberries usually benefit from irrigation 9 years out of 10. However, the cost benefits of irrigation will vary from site to site. If strawberries are grown in soils with a good capacity to hold soil moisture, in areas where spring frosts are not common or where evapo-transpiration rates are low, irrigation will not be needed as frequently.

Considerations

Many technical and financial factors influence what type of irrigation system is selected. An adequate, dependable water supply must be available throughout the growing season. The concentration of soluble salts and pollution from chemicals and bacteria in the water should be tested. If water quality is doubtful, the water should be analyzed. Under the *Ontario Water Resources Act*, a permit from the Ontario Ministry of Environment is required if more than 50,000 litres (11,000 gallons) of water a day will be taken from any source, including a well.

Sprinkler irrigation systems will use more water than trickle or drip irrigation systems. For sprinkler irrigation, plan to use 25–75 cm of water per hectare (4–12 in. per acre) each season (1 acre-inch = 22,610 gallons). Because irrigation systems are not 100% efficient, plan to store at least 150,000 litres (33,300 gallons) for each acre-inch of water applied. The advantages and disadvantages of sprinkler and trickle irrigation systems are shown in Table 3–5, *A Comparison of Sprinkler and Trickle Irrigation Systems for Strawberries,* on page 24. Most strawberry growers choose sprinkler irrigation because it can be used for frost protection and evaporative cooling. For more information, consult the Best Management Practices Publication *Irrigation Management*, available from the Ontario Federation of Agriculture, tel: (416) 485-3333, e-mail: research@ofa.on.ca.

Because strawberries are shallow-rooted and obtain most of their water from the top 30 cm (12 inches) of soil, irrigation should provide adequate soil moisture to a depth of 30 cm (12 inches). Water application rates for sprinklers should be

TABLE 3–5.
A Comparison of Sprinkler and Trickle Irrigation Systems for Strawberries

Sprinkler		Trickle	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
• can be moved from field to field, flexible • can be used for frost protection • can be used for evaporative cooling • helps to incorporate pre-emergent herbicides and increase their effectiveness	• higher initial investment • uses more water • higher energy cost to operate • encourages weed growth between rows • wetted foliage and fruit is more susceptible to disease • pesticide residues may be washed off • spreads soil-borne diseases by splashing	• lower initial investment • uses less water • uses less energy to operate • has little or no effect on weed populations or disease control • well suited for application of fertilizer • less risk of microbial contamination of fruit	• permanent set-up • does not provide frost protection • provides minimal evaporative cooling

adjusted to avoid puddling and run-off. On most Ontario soils, application rates of 6–12 mm (0.25–0.5 in.) per hour are suitable. The spacings for sprinklers and laterals should be such that water is applied uniformly.

Irrigation companies often provide expert technical advice on the design of an irrigation system.

Excessive irrigation should be avoided. Too much water while the fruits are developing results in soft fruit that does not handle or ship well; in addition, fruit rots are likely to be more serious. Too much water hinders normal root action and development, and more nutrients will be leached from the soil. Herbicides can also be leached down into the rooting zone where they might cause injury to the strawberry plants and control weeds less effectively.

Irrigation Scheduling

Strawberries require about 2.5 cm (1 in.) of available moisture per week during the growing season, but this amount varies with weather conditions, the water-holding capacities of the soil and the stage of crop development. Several methods can be used to determine when water should be applied. The simplest but least accurate method is to use the "soil feel test." In this test, with adequate water, the soil will form a ball, and the particles will stick together. If there is too much water, the soil ball can be squeezed to release free water. Another method is to use tensiometers to indicate when irrigation is required. These are most effective on sandy and sandy loam soils where repeated measurements can be taken at the same location. Remember that tensiometers only measure the moisture at one point in the field and at one depth. This may not be accurate where soils are variable.

The most sophisticated way of determining the amount of water needed and when it is needed is to use an irrigation scheduling model. To use this method effectively, growers must determine the available water capacity for their soil type. A soil test is best, but if this cannot be done, the water capacity of a soil can be estimated using Table 3–6, *Available Water Capacity for Soil Textures,* on page 25. Then obtain daily evapo-transpiration values from the local weather service and record daily rainfall and irrigation amounts for each field. Finally, a simple calculation can be done daily to determine the soil water lost due to transpiration and evaporation (evapo-transpiration) and the water gained from rainfall and irrigation. Apply water when the calculated soil-water balance falls to 50% of the available soil moisture for that soil. For more information on irrigation models for strawberries, refer to the OMAFRA Factsheet *Irrigation Scheduling for Fruit Crops,* Order #90-069, and *Best Management Practices: Irrigation Management,* available from the Ontario Federation of Agriculture (OFA) at tel: (416) 485-3333, e-mail: research@ofa.on.ca.

Evaporative Cooling

Excessive heat will cause strawberry fruits and plants to lose water and the quality of the fruit in the field to decline. This will lead to poor post-harvest quality, which lowers prices for the product.

To cool fruit by evaporation, water is applied through the irrigation system to cover the fruit and plants. As the water on the plant surface evaporates, it takes heat from the plant tissues and cools them. Evaporative cooling is most effective in hot dry conditions with low relative humidity. This practice can lower bud and fruit temperature by as much as 8–10°C.

A solid set irrigation system fitted with nozzles that give a fine mist pattern is required for evaporative cooling. Nozzles delivering large water droplets will not work as effectively for cooling. In addition, large water droplets may magnify the sun's intensity on the fruit and cause scald marks.

TABLE 3–6.
Available Water Capacity for Soil Textures

(inches of water/inch of soil = mm of water/mm of soil)

Soil Textures	Available Water Capacity for Soil Textures	
	Range	Average
Sands	0.05–0.08	0.065
Loamy sand	0.07–0.10	0.085
Sandy loam	0.09–0.12	0.11
Loam	0.13–0.17	0.15
Silt loam	0.14–0.17	0.16
Silty clay loam	0.15–0.20	0.18
Clay loam	0.15–0.18	0.17
Clay	0.15–0.17	0.16

Source: *Best Management Practices: Irrigation Management* Agriculture and Agri-Food Canada and Ontario Ministry of Agriculture, Food & Rural Affairs, 1995.

Begin to irrigate when 27°C is exceeded in the shade. Irrigation may also be effective below 27°C when the evapotranspiration rate is high due to low humidity or high winds. Apply the water in short cycles of 15-minute durations, at a low rate of about 2 mm/hour. If plants become very wet, evaporation is not occurring, or the application rate is too high. Be sure to allow sufficient time for the plants to dry before nightfall. A good rule of thumb is to stop irrigating after 2–3 PM, depending on humidity.

Frost Injury and Protection

Frost Injury

Strawberries often bloom in Ontario before the last spring frost. Consequently, strawberry flowers can be injured as the plant is low to the ground, and the blossoms open toward the sky. Straw mulch between the rows tends to contribute to lower field temperatures, because it prevents the soil from warming very much during the day. These characteristics make the strawberry bloom particularly susceptible to frost damage.

There are three types of frost that can cause damage to strawberry plants: radiation frost, radiation freeze and advective freeze. Radiation frosts generally occur on cloud-free nights when heat radiates rapidly from soil, straw and plants.

Radiation frosts can occur with an air temperature as high as 4°C or 5°C if there is a low dew point and no wind, because heat is lost from leaves and flowers more quickly than it is lost from the air. This type of frost is less likely to occur on nights when cloud cover traps the heat, or when a light wind (>6 km/hr) mixes warmer upper air with colder lower air near the strawberry plants.

TABLE 3–7.
Critical Air Temperatures for Strawberry Tissues

Twenty minutes or more at critical temperatures can cause injury. Duration of temperature for injury varies with wind speed, humidity, variety, etc.

	°C	°F
Tight bud	–5.5	22
Balloon bud	–2.2	28
Bloom	–0.5 to –1	31
Green Fruit	–2.2	28

Source: Martsoff and Gerber in *Ohio Strawberry Manual* Bulletin 436. Cooperative Extension Service, Ohio State University.

A radiation freeze occurs when a cold air mass moves in with minimum wind. Here the air is usually below freezing and, as heat radiates from the plant, the flower buds freeze. If the dew point is low enough, there may not be any frost visible, just plant tissue damage.

An advective freeze occurs when a cold, dry air mass moves in, accompanied by wind. Here, freezing occurs very rapidly, which makes frost protection very difficult.

Strawberry buds, blossoms and immature fruit can all be damaged by cold. The critical temperature for injury depends on several factors, including the variety, the stage of development and climatic conditions such as temperature, wind speed and the duration of adverse conditions. Strawberry flowers are most sensitive to frost injury immediately before and during opening. At this stage, temperatures lower than –2°C will cause injury. When flowers are in tight clusters in the crown, they will tolerate temperatures as low as –5.5°C. Table 3–7, *Critical Air Temperatures for Strawberry Tissues,* above, shows critical air temperatures for strawberries at different growth stages. These represent the air temperature at which injury is likely to occur. The critical temperature for plant tissue at which injury occurs is difficult to measure and varies from variety to variety.

When the pistils (female parts) of the strawberry blossom are completely frozen, the centre of the blossom turns black, and no fruit develops (Plate 14). In other cases, only some of the pistils are injured, and misshaped berries result.

Frost injury usually occurs to primary flowers because these are the first to open. Primary flowers also produce the largest and most valuable fruit. The secondary and tertiary fruit will not compensate for the lost primary flowers by increasing their fruit size.

Cultural Practices for Frost Protection

Select a site with good air drainage. Avoid lower areas in the field, and plant later-blooming or frost-tolerant varieties. Plant berries on north-facing slopes and remove mulch later in the spring so that the blossoms develop later when the chance of frost is less likely. Remember that while the latter may protect the plants from frost, they may also result in more winter injury or lower yields.

Sprinkler Irrigation for Frost Protection

Most strawberry growers rely on sprinkler irrigation for frost protection. When water from the irrigation turns to ice, the heat released protects the plant from injury. As long as a thin layer of water covers the ice on the blossoms, they are protected. Irrigation systems for frost protection should have the capacity to irrigate the whole field at one time. Sprinkler heads designed for frost protection should be used as they apply lower volumes of water. Regular nozzles apply too much water and can result in waterlogged soil if irrigation is run for several consecutive nights. The nozzle head should be made of metal rather than plastic, and the spring should be covered to prevent freeze-up. Sprinkler rotation should be somewhat faster than one revolution per minute.

The amount of water applied per hour is based on the amount of wind and the temperature (see Table 3–8, *Amount of Water to Apply for Frost Protection,* above). A rate of 2.5–3 mm is considered adequate to protect to –5.5°C with no wind. More water is required if it is windier or colder. Enough water is being applied if the ice is clear. If the ice is cloudy or milky white, not enough water is being applied to protect the flower. At wind speeds above 16 km/hr or at temperatures below –7°C, sprinkler irrigation can do more harm than good because of the rapid freezing that takes place.

Set up the irrigation system and test it before the danger of frost occurs. Calibrate thermometers in crushed ice with a little water, to make sure they read 0°C. Place thermometers at blossom level in the plant row and in the coldest (usually lowest) areas of the field. A thermometer at ground level just outside the area being irrigated can be used to follow general air temperatures once irrigation is started. Put the thermometers on small blocks of wood with the bulb end extending past the wood. Thermometers that give maximum and minimum readings are useful in determining whether temperatures are falling or rising.

When to Start and Stop Irrigating

Start irrigation during bloom when air temperatures in the lowest part of the field reach 1.1°C. As the irrigation begins, there is rapid evaporative cooling of about 1–2°C. For this reason, the recommended start-up temperature is several degrees higher than the critical temperature for plant injury.

TABLE 3–8.
Amount of Water to Apply for Frost Protection

AirTemp in the Canopy (°C)	Wind Speed at Crop Height (km/h)				
	0–1.5	3–6	8–13	16–23	29–35
–2.8°C	0.25 cm/h	0.25 cm/h	0.25 cm/h	0.25 cm/h	0.50 cm/h
–4.5°C	0.25 cm/h	0.40 cm/h	0.75 cm/h	1.00 cm/h	2.00 cm/h
–6.7°C	0.40 cm/h	0.75 cm/h	1.50 cm/h	2.00 cm/h	—
–7.8°C	0.50 cm/h	1.00 cm/h	1.80 cm/h	2.50 cm/h	—

0.25 cm/hr = 2,250 gals water/acre/hour

Source: Marstoff and Gerber, in *Ohio Strawberry Manual*, Bulletin 436, Cooperative Extension Service, Ohio State University.

Irrigation can be stopped when ice on the plants begins to melt, usually after sunrise. Monitor carefully to make sure that the ice continues to melt and that temperatures remain above freezing. Changes in wind speed could change temperatures near the plant surface. Irrigation should be started up again if the water begins to freeze.

Reducing Water Use

Obviously, to irrigate more than necessary for frost protection is expensive, and water supplies may be limited. Too much water in the field can affect plant growth and cause disease problems.

Intermittent application systems, where nozzles turn on and off during the frost protection period, may provide effective frost control under calm conditions. These systems require constant monitoring of freezing conditions. Growers must ensure that free water is present on the plants at all times. When all the water is frozen, injury can occur.

Less water can be used if the actual temperature inside the plant bud is known. Carefully calibrated and properly placed thermistors will provide this information. Start-up of the irrigation system can then be delayed until the bud temperature, rather than the air temperature, reaches the critical temperature.

Floating Row Covers for Frost Protection

Floating row covers will modify the influence of wind, evaporative cooling, radiative cooling and heat loss. Floating row covers have been reported to provide about 1–2 degrees of frost protection under calm conditions, because plants cool less quickly beneath the cover. Often, temperatures fall so slowly under the cover that irrigation is not needed. If irrigation is required, it can be applied directly over the row cover.

Other Methods of Frost Protection

Straw mulch can be used to re-cover the plants to prevent blossoms freezing. This may be practical for very small acreages. Straw can be left on the plants for a day or two if frost warnings continue, provided daytime temperatures do not get above about 27°C.

Other methods of frost protection such as use of heaters and stirring the air with fans, air-blast sprayers or airplanes are sometimes used. These methods may only increase the air temperature by 1°C or 2°C but may be enough to reduce potentially severe injury to moderate-to-slight injury.

Alternative Production Systems

Growers are increasingly searching for ways to extend the cropping season to compete with imported strawberries, which are available throughout the year from California and Florida. Several production systems that are being commercially adopted in other countries are available.

Whether these systems will be adopted in Ontario will depend on several factors: suitable marketing opportunities, climate, suitable varieties, supply of plants and economic considerations. Growers are advised to investigate these systems carefully before they attempt large-scale plantings.

Variations on the Matted-Row Planting System

Hill System

The hill system is not generally practical in Ontario for June-bearing varieties, however, it can be used when day-neutral varieties are grown. In this system, large numbers of plants are set out, and all runners removed regularly. In the double-row hill system, plants are usually planted 30 cm apart in two rows spaced 30 cm apart. Then a space of 75 cm is left between these two rows and the next set of two rows. This system requires about 50,000 plants per hectare.

Experiments in Ontario have shown that, for most June-bearing varieties, the yield of matted rows equals or exceeds that of the double-row hill system. Earlier ripening and larger fruit size sometimes occur with the hill system, but these advantages are more than offset by the cost of runner removal and the large number of plants needed to plant a hectare.

Narrow, Raised-Row System

In recent years, a few growers in the U.S. and Ontario have grown strawberries in narrow rows on ridges, with very promising results. Methods tend to vary from grower to grower. Ridge height is variable, with a maximum height of 30 cm. Distance between row centres is about 90 cm, although planting double rows 60 cm apart with a space of 90 cm between sets of double rows is also being tried. Planting distances between plants in the row vary from 7.5–12 cm. Limited numbers of runner plants are allowed to root, but the method of training and the number of plants per metre of row varies. Usually the width of the plant area is confined to 15 cm. Excess plants are removed by hand or by mechanical methods.

This system requires special equipment for shaping the ridges, narrow rototillers for renovation and solid-set irrigation. The narrow spacings mean modification of other equipment such as tractors, planters, fertilizer applicators, sprayers, mulching machinery, subsoilers, etc. Growers usually apply most of the fertilizer through irrigation. Considerable effort is required to train and remove runners.

More experience and research with this system are required before its value for Ontario is established. Evaluation of plant spacing and training methods is needed. Raised beds are colder in the winter, and greater winter injury can occur. For growers who want maximum yields and who are willing to give careful attention to all cultural details, narrow, raised rows may have value, especially on heavier soil types.

Ribbon-Row System

This system is a modification of the matted-row and narrow, raised-row systems.

Its objective is to obtain fruit in the first year of a planting. Plants are planted closely together (15–20 cm), and the flowering tresses that emerge are allowed to fruit. This fruit is harvested 2–4 weeks after the normal summer harvest.

Once the fruit has been harvested, the plants are allowed to produce runners, which develop to form a matted row or raised row. By the third year, the plants in the matted rows have become very crowded, and smaller fruit can result.

The profitability of the system has been questioned because of the large number of plants used — 40,000–50,000/ha. Research has shown that eight marketable fruits per plant are needed in the first year for this system to be more profitable than either the matted-row or the hill systems.

Annual Plasticulture System

This system of planting is adopted from the system of annual strawberry culture used in California and Florida. Freshly dug, actively growing transplants or "plug plants" are planted at high densities (43,000 plants/ha). Planting takes place in late summer or early fall on fumigated, raised beds covered with black plastic and equipped with trickle irrigation. The plants are fruited the following spring and then destroyed (Plate 15).

High yields and an extended cropping season have been claimed for this system in the eastern United States. It is becoming extremely popular from New Jersey southwards, where the cultivar Chandler is used. Some growers in Ontario are experimenting with the system.

More experience and research is required to adapt the system to Ontario conditions. Which Ontario-grown varieties are suited to this system is not known. Ideal planting dates have yet to be determined. Growers who wish to try the annual plasticulture system should plant a range of varieties and pay careful attention to the cultural practices used.

Solid-Bed System

From 1965 to 1987, strawberries were grown experimentally in solid-bed plantings at the Horticultural Research Institute of Ontario (Plate 16). In this system, plants are planted out in rows at spacings similar to those of the matted-row system, but runners are allowed to cover the entire area of the planting instead of being confined to rows. Results have been very encouraging. Yields of hand-picked berries have been at least 50% higher than those obtained in matted-row plantings. This system is also a promising way of growing strawberries for once-over machine harvest. There have been no serious problems with solid-bed plantings. Fruit rot has not been a problem when adequate fungicide sprays are applied. Herbicides have given good weed control when used along with irrigation and in the absence of cultivation. Runner plants have rooted well. Plantings have been successfully renovated for a third crop.

Waiting-Bed System

The waiting-bed system of planting is used widely in northern Europe but has not been adopted in North America. The system has three phases: plant production, cold storage and cropping. In the plant production phase, runner plants are planted in beds 30 cm apart, and runners and blossom clusters are removed to encourage plants to produce multiple crowns. These plants are then dug in the fall and cold-stored.

In the cropping phase, the cold-stored plants are planted in rows 30 cm apart at staggered intervals throughout the summer. These plants fruit 45–60 days after planting and produce a continual supply of fruit out-of-season throughout the summer.

Research into adopting this system to Ontario conditions is under way at the University of Guelph. To date, the multicrowned, cold-stored plants are very expensive to produce. And although suitable varieties, like Honeoye and Jewel, have been identified, yields from this system have been disappointing. Until the cultural practices and economics of the system have been established, the system is not recommended for Ontario.

Floating Row-Cover System

Floating row covers, properly applied, can advance the fruiting season by up to 2 weeks. The effect is variable and depends mainly on the climatic conditions during the spring. In years with warm springs, floating row covers do not advance cropping, but in years with cool springs, early crops can be obtained. Growers in Ontario have experienced advances of 1–2 weeks on early varieties. This technology has replaced small plastic tunnels used to advance the season. Spun-bonded floating row covers are placed over the matted rows in late fall or late winter before the overwintering plants start growing (Plate 17). Applying row covers in the fall will encourage late-season growth, which enhances the development of the initiated flower buds. Applying them in late winter only stimulates the new growth in the spring.

The advantages of row covering are earlier berries, higher prices and positive effects on reputation and customer base. Row covers provide some frost protection, although the flower buds open earlier. The disadvantages are that frost protection is required more frequently, the covers must be removed for early-season weed control, the first fruit are often misshapen and the covers must be handled several times and stored.

Remove straw and apply the covers in late March or early April. Secure the edges with sandbags or trench them in. Monitor bud development and protect from frost as necessary. Plants can be irrigated over the floating row cover. Remove the cover at first bloom and pull back on if frost protection is needed. Monitor for pests and apply herbicides, insecticides and fungicides ahead of your normal schedule.

Floating row covers are recommended for growers to advance part of their crop for fresh market or PYO. They can be profitable if the cover is used for more than 1 year and if higher prices are obtained for early berries. They should be used on high-yielding early varieties, but can also be used to advance high-quality main crop varieties.

Plastic Walk-In Tunnel System

Large, plastic walk-in tunnels have been used extensively in several countries to produce early-ripening strawberries.

Tunnel production is a specialized operation and may be more successful in early areas and with early varieties. It could also be useful for fall crops of ever-bearing or day-neutral strawberries, but this use has not been studied in Ontario yet. Benefits, costs and management problems must be considered.

Benefits

Berries can ripen a week to 10 days earlier than normal and one-third to one-half the crop can be harvested by the time the normal crop starts to ripen. Berries from tunnels can compete with imported fresh berries from the U.S.

Costs

There are additional costs associated with plastic tunnels. These include costs of plastic (replaced each year), wire (usable for several years) and polypropylene twine (usable for two or three seasons). Labour is required to install, ventilate and remove the tunnels.

Management Problems

Tunnels need to be ventilated to keep temperatures and humidity down. Misshapen berries will occur if temperature and humidity are too high, or if pollinating insects are not present. Good spray coverage is needed to control fruit rots. However, fruit rots can be reduced if water is not allowed to touch the leaves, flowers and fruit. Wind can blow the tunnels open and disposal of used plastic is a problem. Harvesting labour may be scarce either early or late in the season. For early crops, the small berries produced at the end of the season in tunnels must compete with the large, first-ripening berries of the normal outside crop.

Possibilities for Ontario

These tunnels have been tested by the Horticultural Research Institute of Ontario and by a few Ontario growers.

Large-scale tunnel production is not recommended for Ontario at this time. Further economic and management studies are needed.

For information on small, single-row tunnels, see the section *Floating Row-Cover System* on page 28.

Greenhouse Production

Greenhouse production of strawberries for early markets has been practiced commercially in Europe since the 1940s (Plate 18). Initial culture was in soil, then various water-based methods such as hydroponics, aero-hydroponics and nutrient film techniques were used. These have been abandoned in favour of substrate cultures using buckets or bags.

Greenhouse culture in Ontario has the potential to give year-round strawberry production, but this fruit would have to compete with out-of-season strawberries from California and Florida. Presently, it is possible to harvest strawberry varieties using day-neutral varieties or "waiting-bed"-type, June-bearing varieties in greenhouses throughout the year. However, the varieties and cultural practices are still being researched, and the economics of the systems need to be evaluated. Only when these issues have been resolved satisfactorily can the system be recommended.

Dutch growers produce 120–130 t/ha of strawberries annually in greenhouses. At current North American prices for strawberries, those yields give total returns that are considerably less than can be obtained with greenhouse vegetables.

Substrate culture has several advantages: soil-borne nematodes and the root diseases red stele, phytophthora crown rot, leather rot and verticillium wilt can be easily controlled. Herbicides are not necessary, and botrytis grey mould can be prevented. The strawberries can be picked standing or sitting 30–40% faster than in field plantings. The fruits are clean and ripen uniformly.

Plants are planted in high densities, up to 160,000 plants/ha in various substrates. The substrates commonly used are 80% peat:20% perlite, although others using rockwool are being investigated. Nutrients are being supplied through drip irrigation and need to be closely controlled. Pollination can be done effectively with bumble bees.

June-bearing varieties will need to be planted in sequence to obtain several crops. Day-neutral varieties should be planted in early May or early January. All varieties take about 90 days from planting to produce fruit.

Greenhouse temperatures should be controlled at 18°C–20°C during the day and 14°C–16°C at night. Plants should be grown in long days, which can be induced when days are short by giving the plants 1 hour of light (40 w/sq m) in the middle of the night. Supplementing light, although desirable, is very expensive and is not used commercially.

Day-Neutral Production

Day-neutral strawberries differ in fruiting habit from June-bearing varieties. Older ever-bearing varieties have now been superceded by newer day-neutral varieties.

Day-neutrals produce a fall crop in the year of planting; in subsequent years, the production cycle peaks every 6 weeks from June onwards. After the first year, the spring crop starts about 4–7 days before the early-season, June-bearing varieties, such as Veestar.

Modified cultural systems are necessary to produce high-quality, high-yielding day-neutral strawberries. Some growers have had poor success with day-neutral varieties because they have treated them as conventional June-bearing varieties. Research during the last several years has shed new light on how to grow day-neutrals strawberries as a commercial crop.

Expectations

Total yields of day-neutral varieties are quite high. At 50,000 plants/ha, yields of more than 34 t/ha can be attained the year of planting and in subsequent years. Not all of this production is marketable, because some berries are small, damaged by tarnished plant bug or rotten. Observations over several years suggest that a reasonable marketable yield for a well-managed bed is 13.5 t/ha. In the second year, at least half the fruit ripens with the June crop, and the remainder is spread throughout the later growing season. Hot summers seem to be more detrimental to second-year plantings.

Present recommendations are that day-neutral varieties be cropped during the first growing season, overwintered and harvested the following June. The plants should then be destroyed, and the summer crop taken from a new planting. Continued harvesting after the June crop in the second year is not recommended, because weed, pest and disease problems become more severe and fruit tends to be smaller.

Culture

Day-neutrals respond well to raised beds with trickle irrigation and black plastic mulch (Plate 19). The raised bed and black plastic mulch allow the root system to warm in spring, while the trickle irrigation lines provide water and nutrients. Black plastic mulch helps to conserve soil moisture and almost eliminates weed competition; its use can increase yields by up to 50% in the first year compared to unmulched plantings. Some growers use white plastic, because it keeps soil and fruit cooler in hot weather.

If black plastic mulch and raised beds are not a viable option, then a flat bed may be used if the soil is thoroughly worked. If plants are set on a flat bed, place weed-free straw around them. This will help plants become established, cool the soil and retain moisture.

Day-neutrals perform best when planted at high densities with runners removed. A staggered double row with plants set 20 cm apart, offset 10 cm from centre, with 1.2 m between row centres, is a very efficient planting design. At plant densities of 50,000/ha, double rows yield 30% more than single rows.

Remove runners from all plants throughout the season. Fewer runners are produced after fruiting begins, so, while this task is somewhat intensive early in the season, it becomes insignificant later.

Flowers should be removed for 6 weeks following planting to allow the plants to achieve sufficient size for fruiting. If this is not done, the plants will be small and yields low. If the period of flower removal is extended beyond 6 weeks, the plants, berries and second-year yield will be larger, but fewer berries will be produced in the first year.

Day-neutrals benefit from a continuous supply of nitrogen and potassium. Additional phosphorus is not required, provided an adequate supply has been incorporated before planting.

An adequate supply of nitrogen (N) can be applied in three ways. The first is to apply 34 kg/ha N monthly throughout the growing season. The second is to use a slow-release fertilizer at planting. The third option is to apply 5 kg/ha N through the drip irrigation system weekly. Calcium nitrate is the preferred source of nitrogen early in the season, but urea can be substituted when the weather warms up.

For soils that are low in potassium, such as sandy soils, supplement the preplant potassium during the growing season with 11 kg/ha K_2O at monthly intervals or 2 kg/ha K_2O at weekly intervals through the drip irrigation system.

Day-neutrals tend to be heavy consumers of boron because of their large commitment to reproduction. Monitor leaves occasionally to ensure that boron levels do not fall below 30 ppm. Two kg/ha of solubor can be applied in midsummer if boron levels are too low. The phosphorus:zinc ratio in the leaves should remain below 140 and the zinc level above 20 ppm. Because phosphorus hinders zinc uptake, balanced fertilizers containing phosphorus are not recommended if the soil has been amended properly before planting.

Varieties

The day-neutral varieties that are currently available tend to have small fruit. However, some growers have had success with the variety Seascape. New day-neutral varieties are being developed, so growers should check the current variety recommendations (see the section on *Day-Neutral Varieties* on page 38).

4. Varieties

Choosing a Variety

Choose varieties suited to local conditions that will provide a range of picking dates (early, mid-season and late) and are best suited for the intended market (i.e., PYO, retail, wholesale or processing). The main characteristics of common varieties are given in Table 4–1, *Notes on Strawberry Cultivars,* on page 32. A list of the current recommended varieties is available on the OMAFRA Web site at www.gov.on.ca/omafra/english/crops. New varieties should be evaluated in small quantities on the farm before large plantings are made.

A variety may be chosen because of its resistance to pests and diseases. For example, varieties that are resistant to red stele or black root rot are recommended for heavy or poorly drained soils. Where there is a history of disease in previous plantings, varieties that have some resistance to those diseases are recommended. Table 4–2, *Strawberry Variety Ratings for Resistance to Diseases,* on page 34, outlines the resistance of recommended varieties to common diseases. Table 4–3, *Strawberry Variety Ratings for Resistance to Pests and Nematodes,* on page 35, outlines resistance to pests and nematodes.

Variety Descriptions

Descriptions are based on performance under Ontario conditions in research trials and, wherever possible, growers' plantings. Fruit descriptions are for fresh fruit. The term "processing" in these descriptions refers mainly to frozen and canned packs. Most varieties make acceptable jam. Much of the processing information is based on extensive tests done at the Horticultural Research Institute of Ontario (HRIO), Vineland Station. Descriptions also include the results of hulling (decapping) tests conducted at HRIO Vineland and HRIO Simcoe using a commercial hulling machine manufactured by Canners' Machinery Ltd., Simcoe, Ontario.

Where a variety is recommended for solid-bed production and mechanical harvesting and processing, a statement to that effect is included.

Note that for some varieties, sensitivity to Sinbar (terbacil) in Ontario has not been determined.

June-Bearing Varieties

Allstar

Introduced in 1981 by the University of Maryland and the U.S. Department of Agriculture (USDA), Maryland, Allstar is vigorous and productive, and produces very large, firm fruit of good quality in late mid-season. It is resistant to red stele. Sensitivity to Sinbar in Ontario has not been determined. Allstar is recommended for trial in Ontario.

Annapolis

An early-season, productive variety introduced by Agriculture and Agri-Food Canada (AAFC), Kentville, Nova Scotia, in 1984, Annapolis produces large, firm, medium-red, glossy berries with a good flavour. Annapolis is good as a frozen pack. Plants produce runners freely and are vigorous, winter-hardy, susceptible to mildew but tolerant to red stele. Annapolis is very sensitive to Sinbar. Annapolis is recommended for limited, early production for pick-your-own sales and the fresh market.

Blomidon

A late-season, productive variety, introduced by AAFC, Kentville, Nova Scotia, in 1984, Blomidon produces large, firm, medium-red, glossy berries with an excellent flavour. Blomidon can be picked very easily but is somewhat difficult to hull. Plants, which produce runners freely, are very vigorous and winter-hardy. Blomidon is susceptible to mildew, but resistant to some strains of red stele. Sensitivity to Sinbar in Ontario has not been determined. Blomidon has June yellows and is no longer propagated.

Bounty

Introduced in 1972 from AAFC, Kentville, Nova Scotia, Bounty produces late season and is very productive. The berries are medium to medium-dark red, somewhat dull and seedy in appearance, moderately firm, with very good flavour and fairly good as a frozen pack. Some hulls come off during picking; berries hull fairly well with the old-type hulling machine. Berries are moderately large in early pickings, but small in later ones. Plants are vigorous

TABLE 4–1.
Notes on Strawberry Cultivars

Season[1]	Cultivar[2]	Size[3]	Strong Points	Weaknesses	Best Suited To
Very early 2.5 days ahead	**Mohawk**	Moderate 7.7–9.3 g	Bright colour, firm, good flavour. Resistant to red stele, tolerant to mildew.	Average yields, lower than Veestar. Size drops off after 2 pickings. King berries may be irregular in shape.	Trial variety for early local markets and shipping.
Early	**Veestar**	Moderate 6.6–8.8 g	Excellent flavour. High yield.	Moderately soft, poor for shipping. Tends to be dark.	PYO throughout the province.
Early 0.5 days	**Annapolis**	Moderate-Large 9.6–10.2 g	Orange-red colour. Acceptable firmness and shelf life (firmer than Veestar). Resistant to red stele.	Not as productive as Veestar. Susceptible to mildew and angular leaf spot. Sensitive to Sinbar.	Early production for PYO and fresh market. Does better on medium-textured soils than heavy soils.
Early 2 days	**Northeaster**	Large 10.2–15 g	Large, firm, bright fruit with strong flavour. Resistant to red stele.	Susceptible to powdery mildew. Mediocre yield.	For trial only.
Mid 2.2 days	**Chambly**	Moderate 8.7–11.9 g	Deep-red fruit with red flesh and strong skin. Very productive. Good flavour. Similar firmness to Kent.	Fruit is soft in southwestern Ontario and may be too dark when overripe.	Performs well in eastern Ontario and southern Quebec. For trial only.
Early-mid 2.5 days	**Honeoye**	Moderate 8.1–8.9 g	Good yield. Relatively firm berry. Bright fruit. Consistent size throughout season.	Sharp or variable taste, depending on site. Dark in colour when overripe. Tip of fruit ripens last. Somewhat sensitive to Sinbar. Susceptible to black root rot.	Widely adapted to different soils and conditions.
Early-mid 2.5 days	**Glooscap**	Moderate 7.7–9.2 g	Good size initially. High yield. Good winter hardiness. Decaps easily.	Poor-to-fair runnering. Dark colour with pale, raised seeds. Likely sensitive to Sinbar.	Gaining popularity for PYO, especially in eastern and northern Ontario. Also popular in midwest U.S.
Early-mid 2.5 days	**Settler**	Large 11–12 g	Large, bright, attractive fruit. Similar to Governor Simcoe, but earlier.	Weaker skin than Governor Simcoe. Bleeds in hot weather. Not as productive as Kent or Honeoye. Somewhat sensitive to Sinbar.	Better adapted to heavier soils than Governor Simcoe. Suitable for PYO.
Mid 3 days	**Cavendish**	Very large 12.2–14.4 g	Very large fruit. High yields. Resistant to red stele.	Tends to ripen unevenly, white shoulder on fruit. Skin can be tender. Dark colour. Soft in hot weather. Sensitive to Sinbar. Very susceptible to angular leaf spot.	Not suited to southwestern Ontario. Better adapted to eastern and northern Ontario.
Mid 3.5 days	**Kent**	Moderate-Large 10.1–13.0 g	Excellent yield. Fair for shipping from cooler areas of Ontario.	Skin can be weak in hot conditions (not as strong as Honeoye). Very susceptible to leaf spot, leaf scorch and angular leaf spot. Can be dark in colour. Very sensitive to Sinbar. Will produce multi-crown plants in hot conditions.	Does well on both sandy loam and clay loam soils. Does not do well on hot sandy soils. Sensitive to extremely hot weather.
Mid–mid-late	**Mira**	Similar to Kent	High yields of bright, light-red berries. Uniform conical shape with high neck. Firmer than Kent. Resistant to red stele and most leaf diseases. Maintains good size for several pickings.	Flavour fair and maybe tart. Sensitive to Sinbar.	For trial only. Suitable for fresh market.

TABLE 4–1.
Notes on Strawberry Cultivars

Season[1]	Cultivar[2]	Size[3]	Strong Points	Weaknesses	Best Suited To
Mid 3.5 days	**Jewel**	Large 10.6–11.5 g	Bright and glossy red. Good yield, but not as productive as Honeoye or Kent. Firm. Very conical in shape. Good for freezing.	Susceptible to winter injury. Bland flavour. Sensitive to Sinbar. Susceptible to leaf spot.	Well adapted to heavier soil types. Suitable for fresh market. For trial only.
Mid-season 4 days	**G19**	Large 10–12.8 g	Firm, good yield, freezes well. Orange-red in colour. Firm, moderately shiny skin. Resistant to powdery mildew.	Fruit can be slightly irregular. Susceptible to leaf blight. Flavour only fair. Somewhat sensitive to Sinbar. Did not do well in New Liskeard trials.	For trial only. Suitable for fresh market.
Late-mid 4 days	**Allstar**	Large 9.8–12.5 g	Good flavour. Firm fruit. Orange-red in colour. Uniform size and shape.	Size drops off after 2 pickings. Prominent seeds.	Very popular in Michigan and U.S. For trial only.
Mid-late 5.5 days	**Governor Simcoe**	Large 9.2–11.6 g	Firm berry with strong skin. Good for shipping. Bright, medium-red, attractive fruit. Slightly pale. Mild, pleasant flavour.	Susceptible to powdery mildew. Production can be inconsistent in cooler regions and on heavier soils. Somewhat sensitive to Sinbar.	Best suited to lighter textured soils.
Late 6 days	**Latestar**	Large 10–13.2 g	Firm, tough-skinned, fruit, glossy colour, mild acidic flavour. Very productive. Resistant to red stele and most fungal leaf diseases and fruit rots.	Performance is variable at different sites. Average fruit quality at Simcoe. Susceptible to leaf blight. Very vigorous plants.	For trial only. Adapted to plasticulture.
Late 6.2 days	**Startyme**	Large-Very large 12.5–14.1 g	Very regular, light-red fruit. Moderate fruit firmness and skin strength. Vigorous plants. Large fruit. Berries can be picked with cap off.	Fruit decaps easily. Susceptible to powdery mildew and leaf spot.	For processing and PYO. For trial only.
Late 6 days	**Micmac**	Moderate-Large 8.5–10.3 g	Brightly coloured fruit. Fair for shipping. Maintains size throughout season.	Somewhat pale in colour. Yields less than some cultivars. Very sensitive to Sinbar.	PYO
Very late 7.5 days	**Bounty**	Moderate 8.0–9.0 g	Good flavour.	Dark in colour. Tends to produce many small berries. Very sensitive to Sinbar. Soft.	PYO
Late–mid-season	**Winona**	Large	Productive, late-season variety. Large, firm berries with light-red, shiny colour. Winter hardy. Tolerates Sinbar. Resistant to red stele.	Berries are uneven in shape, dimpled. Long flower stalks, berries get tangled. May be difficult to pick. Susceptible to leaf diseases, including angular leaf spot.	For trial, PYO and fresh market.
Very late 7.5 days	**Scotland**	Large 9.9–11.3 g	Very firm. Conical shape. Large leafy calyx.	Very firm. Size drops off after first pick. Seeds turn dark.	Suited for machine harvest or processing. For trial only.

[1] Average number of days to 25% harvest after Veestar, in Ontario trials (mostly at Simcoe).

[2] Varieties that have been developed in Nova Scotia tend to perform better in eastern Ontario than in southern Ontario.

[3] Size descriptions are based on trials for 2–4 years at Simcoe and Vineland.
Check the OMAFRA Web site for updates at www.gov.on.ca/omafra/english/crops

and produce runners well, but are susceptible to verticillium wilt and are moderately sensitive to Sinbar. Bounty is useful for pick-your-own plantings and home gardens.

Cabot

A mid- to late-season variety, introduced by AAFC, Kentville, Nova Scotia, in 1998, Cabot produces fruit about 1 day later than Blomidon. Berries are very large, bright red and very juicy with a firm flesh but less firm

TABLE 4–2.
Strawberry Variety Ratings for Resistance to Diseases

Cultivar	Leaf Spot	Leaf Scorch [1]	Powdery Mildew	Botrytis Rot	Verticillium	Red Stele Races [2]					Angular Leaf Spot [3]
						C-4	C-3	C-2	C-6	C-7	
Allstar [4]	MR	S	MR	MR	MR	R	MR	R	S	?	HS
Annapolis	MR	MR	S	S	MR	R	R	R	R	S	HS
Bounty	MR	MR	MR	MR	HS	S	S	R	R	R	S
Cavendish	MR	R	MR	MR	MR	R	R	R	R	S	ES
Chambly	R	MR	R	?	?	?	S	MR	S	?	?
Glooscap	MR	MR	MR	S	S	S	S	S	S	S	S
Governor Simcoe	MR	MR	HS	MR	MR	S	S	S	S	S	S
Honeoye	MR	R	MR	MR	HS	S	S	S	S	S	HS
Jewel [5]	HR	MR	HR	MR	S	S	S	S	S	?	HS
Kent	HS	S	MR	S	S	S	S-MR	S-MR	S	S	HS
MicMac	S	HS	MR	S	MR	S	S-MR	S-MR	S	S	S
Mohawk [6]	?	MR	MR	?	?	R	HR	HR	MR	?	?
Redcoat	MR	MR	MR	HS	S	?	S	S	S	S	MR
Scotland	MR	R	MR	MR	MR	?	?	?	?	?	?
Settler	MR	MR	HS	MR	MR	?	?	?	?	?	S
Sparkle	S	MR	MR	MR	S	S	HR	S	HR	HR	?
Startyme	S	S	S	?	?	?	?	?	?	?	?
Tribute	MR	MR	S	MR	R	R	R	MR	MR	?	?
Tristar	MR	MR	S	MR	R	R	R	R	MR	?	?
Vantage	R	R	R	MR	R	?	R	R	R	?	S
Veestar	S	MR	S	MR	MR	S	R	S	R	S	MR
Vibrant	MR	R	S	MR	S	?	?	?	?	?	?

HR = Highly Resistant R = Resistant MR = Moderately Resistant S = Susceptible
HS = Highly Susceptible ES = Extremely Susceptible ? = Unknown
The following Canadian races equate to American races C-2 = A-6, C-3 = A-4, C-4 = A-3, C-6 = A-7.

[1] Xue, Sutton, Dale and Sullivan 1996.
[2] Red stele ratings from Dr. N. Nickerson and Dr. A. Jamieson, Agriculture Canada, Kentville, Nova Scotia.
[3] Based on field observation in Ontario.
[4] Dr. Gene Galletta, USDA, Maryland (1991).
[5] Dr. Marvin Pritts, Cornell Univ. NY (1991).
[6] Dr. J. Maas, USDA, Maryland.

skin. Primary berries are often somewhat asymmetrical, but later berries even out. Plants are large, and production of runners may be poor if nutrition or irrigation are insufficient. It is resistant to several races of red stele. Sensitivity to Sinbar in Ontario has not been determined. In Nova Scotia, early trials suggest that an effective program to control grey mould will be required in wet years.

Cardinal

Introduced in 1974 from Arkansas, Cardinal produces fruit mid-to-late season and is fairly productive. The berries have medium-dark red skin and are somewhat dull and unattractive, with medium-red, bright flesh. They are very firm, fairly large, fairly acid and good as a frozen pack. Sensitivity to Sinbar in Ontario has not been determined.

Cavendish

A mid-season, productive variety introduced by AAFC, Kentville, Nova Scotia, in 1990, Cavendish produces very large and moderately firm berries with a medium-firm skin. They are bright and medium red, and darken with maturity. Plants are moderately vigorous, susceptible to mildew, moderately resistant to verticillium wilt, resistant to the common races of red stele and sensitive to Sinbar. Cavendish is recommended as a pick-your-own, fresh market variety, but not in southwestern Ontario where it becomes dark and soft in the hot weather.

Chambly

Introduced by McGill University, Quebec, in 1990, Chambly is a very productive variety. The berries are medium-sized, moderately firm and a bright, deep red.

TABLE 4–3.
Strawberry Variety Ratings for Resistance to Pests and Nematodes

	Tarnished Plant Bug[1]	Two-Spotted Spider Mite [2]	Root-Lesion Nematode [3]
Allstar	HS	MR	HS
Annapolis	S	R	HR
Bounty	?	R	MR
Cavendish	?	?	R
Glooscap	S	R	MR
Governor Simcoe	?	R	MR
Honeoye	MR	S	MR
Jewel	?	S	?
Kent	HS	R	HS
Micmac	HS	MR	HR
Redcoat	S	R	HS
Scotland	?	?	MR
Settler	?	?	MR
Sparkle	MR	S	HS
Tribute	?	MR	?
Tristar	?	S	?
Vantage	?	?	HS
Veestar	S	MR	HS
Vibrant	?	?	HS

HR = Highly resistant R = Resistant MR = Moderately Resistant
S =Susceptible HS = Highly Susceptible (or sensitive)

[1] Handley, Dill and Pollard, 1991.
[2] Ferrer, Scheerens and Erb, 1993.
[3] Dale and Potter 1998.

The plants have low vigour but are winter-hardy and resistant to mildew. Sensitivity to Sinbar in Ontario has not been determined. Chambly is recommended for trial in northern and eastern Ontario.

Delmarvel

A disease-resistant variety, introduced by USDA, Beltsville, Maryland, in 1994, Delmarvel produces large, firm fruit with a good colour, with some rot resistance. Delmarvel produces early- to mid-season with low yields in trials at Simcoe. It is resistant to five races of red stele and to most leaf and stem diseases. Limited trials in Ontario suggest that it is not promising for this province. (Sensitivity to Sinbar in Ontario has not been determined.)

Earliglow

Introduced in 1975 from Maryland, Earliglow is an early-season type with fair productivity that is fairly good for frozen packs. The berries are dark red throughout, somewhat seedy, dull, unattractive, firm, of medium size, with fairly good flavour. This is the major early variety in the northeastern U.S. (Sensitivity to Sinbar in Ontario has not been determined.)

G19

Introduced by the Horticultural Research Institute of Ontario in 1998, G19 has similar productivity, fruit size and harvest season to Kent. G19 fruit is slightly paler and very firm, with a glossy, strong skin and mild flavour. Some fruits can be slightly uneven. The plants are vigorous, with pale leaves, and are tolerant to leaf scorch, leaf spot and mildew but susceptible to leaf blight. Its reactions to verticillium wilt and red stele are not known. The plants will at least tolerate low rates of Sinbar. It is recommended for trial for fresh market and pick-your-own.

Glooscap

Introduced in 1982 from AAFC, Kentville, Nova Scotia, Glooscap is an early mid-season, productive variety with medium-size, medium-firm fruit with medium-to-dark red, glossy skin. The fruit hulls easily and can be an acceptable frozen product. The plants are vigorous and produce runners freely, but are susceptible to red stele. Sensitivity to Sinbar in Ontario has not been determined. Glooscap is recommended for limited planting in eastern and northern Ontario.

Governor Simcoe

Introduced in 1985 by the Horticultural Research Institute of Ontario (HRIO), Governor Simcoe is a mid- to late-season, productive berry. The berries are large and firm and have a good, fresh flavour. The skin is a bright, medium red; the flesh is pale. The plants are vigorous, slightly dense and produce runners well but not excessively. Governor Simcoe is moderately resistant to verticillium wilt and leaf scorch, susceptible to powdery mildew and moderately sensitive to Sinbar. It is recommended as a fresh market variety, particularly in sandy soils.

Guardian

Introduced in 1969 by the University of Maryland and the USDA, Maryland, Guardian is a late, mid-season, productive type. The berries are medium-light red, bright, firm, somewhat larger than Redcoat, fair-to-poor in flavour and fair-to-poor as a frozen pack. Early berries have ridges and prominent necks, while berries from later picks are more regular in shape and more attractive. Plants are vigorous, produce runners well, are fairly resistant to verticillium wilt but moderately sensitive to Sinbar.

Honeoye

Introduced in 1979 from the New York State Agricultural Experiment Station (NYSAES), Geneva, New York, Honeoye is an early-mid-season, vigorous type. The large, bright-red, moderately firm berries have a tender skin. This variety is very productive throughout the northeastern U.S., but is susceptible to verticillium wilt and red stele. Sensitivity to Sinbar in Ontario has not been determined. Honeoye is recommended as a pick-your-own variety.

Jewel

A mid-season, productive variety introduced by NYSAES, Geneva, New York, in 1985, Jewel produces large, firm, medium-dark red berries. Jewel is resistant to mildew and leaf scorch but susceptible to red stele and verticillium wilt. Sensitivity to Sinbar in Ontario has not been determined. Jewel performs well on heavy soils and is recommended for trial as a pick-your-own and fresh market variety.

Kent

Introduced in 1982 from AAFC, Kentville, Nova Scotia, Kent produces large, moderately firm, very dark-red berries suitable for fresh market only. The plants are vigorous and productive. Kent is susceptible to red stele or verticillium wilt and is very susceptible to Sinbar. Kent is recommended for central, eastern and northern Ontario.

Lateglow

A mid-late-season variety of average productivity introduced by USDA, Beltsville, Maryland, in 1988, Lateglow produces large, firm, bright, medium-red berries with good flavour. The plant produces runners well and is highly resistant to red stele and verticillium wilt. Sensitivity to Sinbar in Ontario has not been determined. Lateglow is not recommended for Ontario.

Latestar

Introduced by USDA, Beltsville, Maryland, in 1995, this large-fruited variety has acceptable yields in the mid-late season. The fruit is moderately firm with a glossy red skin and a mild, slightly acidic flavour. It is resistant to five races of red stele and resistant to most leaf diseases. Sensitivity to Sinbar in Ontario has not been determined. Limited trials in Ontario have indicated that Latestar is worthy of further trials.

Lester

A mid-season variety of average productivity introduced by USDA, Beltsville, Maryland, in 1984, Lester produces large, firm berries with good flavour. Lester is resistant to red stele. Sensitivity to Sinbar in Ontario has not been determined.

Micmac

Introduced in 1977 by AAFC, Kentville, Nova Scotia, this productive variety produces in late season. The berries are large, light red, slightly pale, bright, attractive and fairly firm, but may show some bruises. They have fairly good flavour but are only ranked fair to poor for frozen packs. The plants are very vigorous with moderate runner production but are very sensitive to Sinbar. Micmac is recommended as a late berry for shipping and local fresh markets. It is inferior to Bounty in flavour and as a frozen pack.

Midway

Introduced in 1960 from the University of Maryland and the USDA, Maryland, this is a mid-season, moderately productive berry. The berries are medium-red, fairly bright, medium in size, medium-firm, medium-acid flavour and are good for processing. They darken in storage. Some hulls come off during picking, but Midway hulls fairly well with the hulling machine. The plants are vigorous, produce runners well, are susceptible to verticillium wilt, but are only moderately sensitive to Sinbar. Midway is recommended as a variety that is suitable for solid-bed production and mechanical harvesting and processing.

Mira

Introduced by AAFC, Kentville, Nova Scotia, in 1996, Mira is very productive in Nova Scotia, often exceeding Kent in yield, and ripens about 2 days later than Kent. Fruit is similar in size to Kent, is slightly lighter and does not darken excessively when overripe. It is resistant to most foliar pathogens as well as the common races of red stele. Sensitivity to Sinbar in Ontario has not been determined.

Mohawk

Introduced by the USDA, Beltsville, Maryland, the University of Maryland, and the Horticultural Research Institute of Ontario (HRIO) in 1995, Mohawk is a very early ripening variety that has ripened 2–3 days earlier than Veestar in HRIO trials at Simcoe and Vineland. Its glossy, medium-large fruit is an irregular, short conic shape, with a deep-scarlet exterior and pink interior. The flesh is juicy with a firm texture, and the skin is firm. The fruit has a good shelf life and has a mild, sweet flavour. Its yields are average and it is resistant or tolerant to powdery mildew, leaf scorch and leaf blight and resistant to at least six races of the red stele causal organism. Sensitivity to Sinbar in Ontario has not been determined. Mohawk is recommended for trial as an early variety.

Nanaimo

Introduced by AAFC, Vancouver, British Columbia, in 1995, Nanaimo produces medium-to-large fruit with a bright, medium-red external and internal colour. Nanaimo ripens mid- to late mid-season with average yields at Simcoe. Nanaimo is somewhat susceptible to powdery mildew and tolerant to the aphid-borne virus complex. Sensitivity to Sinbar in Ontario has not been determined. Nanaimo is not recommended for Ontario.

Northeaster

Introduced by USDA, Beltsville, Maryland, and Rutgers University, Northeaster produces large, firm fruit with a strong flavour and aroma. It has average yields, ripens early and appears more adapted to heavier soils. Resistant to five races of the red stele causal organism, Northeaster is susceptible to powdery mildew. Sensitivity to Sinbar in Ontario has not been determined.

Primetime

Introduced by USDA, Beltsville, Maryland, in 1995, Primetime produces average-to-large berries, with bright, scarlet, medium-firm skin and medium-firm flesh. The berries have a mild, lightly aromatic flavour. This mid-season variety is resistant to five races of the red stele causal organism and tolerant to leaf diseases. Sensitivity to Sinbar in Ontario has not been determined. It is adapted to heavier soils and was not productive in southwest Michigan. Limited trials in Ontario suggest that Primetime is not promising for this province.

Redcoat

Introduced in 1957 from Agriculture Canada, Ottawa, Redcoat produces medium-red, attractive berries that retain their attractiveness after storage, are somewhat soft but of good size, maintain their size well but have only fair flavour. The fruit is very susceptible to botrytis grey mould. Redcoat is suitable for jam, but the quality of the frozen pack is only fair to poor. The plants are strong, produce runners extensively, are susceptible to verticillium wilt, but are resistant to mildew and relatively tolerant to Sinbar. Once the leading commercial variety in Ontario, Redcoat has now been superceded by newer, larger fruited varieties and is no longer recommended.

Sable

An early variety introduced by AAFC, Kentville, Nova Scotia, in 1998, Sable is larger-fruited and more productive than Veestar. Its berries are moderately firm, bright and attractive with a very good flavour. Plants are vigorous and resistant to several races of red stele. Sensitivity to Sinbar in Ontario has not been determined.

Scotland

Introduced by HRIO in 1991 as a late-season, productive type, Scotland produces berries that are extremely firm and slightly pale red, with a slightly acid flavour. Scotland is acceptable for processing and produces more decapped berries on the Canners Machinery Inc. decapper than Midway. The plant is vigorous and will produce a good solid bed suitable for machine harvesting. It is moderately resistant to leaf scorch, mildew and verticillium wilt. Sensitivity to Sinbar in Ontario has not been determined. Scotland is recommended for trial as a late variety to replace Bounty and for machine harvesting for processing.

Settler

An early-mid-season, productive variety introduced by the Horticulural Research Institute of Ontario (HRIO) in 1988, Settler produces large berries that are firm and bright, medium-red with good flavour. The fruit will skin fairly easily, which could be a disadvantage for shipping. The plants are vigorous but slightly dense. Settler is moderately resistant to leaf scorch and verticillium wilt but susceptible to mildew. Sensitivity to Sinbar in Ontario has not been determined. Settler is recommended for trial as a pick-your-own and fresh market variety.

Sparkle (Paymaster)

Introduced in 1942 by the New Jersey Agricultural Experiment Station, New Jersey, this variety is late-season and productive. The berries vary from medium-light to medium-dark red. They are bright, attractive and soft, with good flavour, but only fair for processing. The berry size is good in early pickings but small in later ones. The plants are vigorous and produce runners excessively. The variety is susceptible to verticillium wilt, leaf scorch and leaf spot, but relatively tolerant to Sinbar. Sparkle is of value in northern Ontario as a late, good-quality dessert berry for pick-your-own plantings and local markets.

Startyme

Introduced in 1995 by the Horticulural Research Institute of Ontario (HRIO) and the University of Guelph, Startyme is a mid- to late-season, productive berry that ripens slightly later than Governor Simcoe. Its fruit is large, firm, even-sized with uniform shape and bright and has an acceptable flavour. The calyx separates easily from the fruit, but with extra care, the fruit can be picked with the calyx attached. The plants are vigorous and susceptible to mildew, somewhat susceptible to leaf scorch and susceptible to leaf spot. The plants will tolerate at least a low rate of Sinbar. Startyme is recommended for trial for fresh market, pick-your-own and processing.

Totem

Introduced in 1971 by AAFC, from British Columbia, Totem ripens late in the season and is unproductive. The berries are of uniform shape, medium-dark red, somewhat dull, with an inferior, medium-dark, bright colour. The fruit is firm, of good size and good flavour, and good for frozen packs. Totem hulls fairly well on hulling machines. The plants are moderately vigorous, somewhat sparse in runnering, are tolerant to verticillium wilt and relatively tolerant to Sinbar. Totem is not recommended for Ontario.

Vantage

Introduced in 1980 by the Horticulural Research Institute of Ontario (HRIO), Vantage is a late-season, productive type. The fruit is medium-large, firm and bright, with medium red skin and good flavour. The plants are vigorous, produce runners freely and are resistant to verticillium wilt, leaf scorch and powdery mildew. Sensitivity to Sinbar in Ontario has not been determined. Vantage is a good, general-purpose berry.

Veestar

Introduced in 1967 by the Horticulural Research Institute of Ontario (HRIO), Veestar is an early, very productive berry, generally equalling Redcoat in productivity. The berries have medium-red, bright, attractive flesh, with moderately firm flesh but tender skin. They are of good size and good flavour, and are good for processing but difficult to hull on the old-type hulling machine. Veestar shows some resistance to botrytis grey mould. The plants are vigorous, moderately resistant to verticillium wilt and relatively tolerant to Sinbar. The variety is outstanding for pick-your-own plantings, local fresh markets and home gardens but is not firm enough for shipping.

Vibrant

Introduced in 1967 by HRIO, Vibrant is an early-mid-season, productive berry. The berries are medium-dark red, bright and fairly attractive. The internal colour is a vivid medium-red throughout. The fruit has medium-firm flesh but tender skin, good size and fairly good flavour. Vibrant is excellent for processing, but difficult to hull with the old-type hulling machine. It shows some resistance to botrytis grey mould. The plants are vigorous, tend to produce runners excessively, are susceptible to verticillium wilt (similar to Redcoat), resistant to leaf scorch, and relatively tolerant to Sinbar. Vibrant is useful in pick-your-own plantings, local fresh markets, processing and home gardens. It is too dark and soft for distant shipping.

Winona™

Introduced by the University of Minnesota and USDA, Beltsville, Maryland, in 1996, this late-season variety is productive and bears large fruits. The fruits are glossy and scarlet, with a slightly aromatic flavour. It is resistant to five races of red stele and has moderate to high resistance for the common leaf diseases. Sensitivity to Sinbar in Ontario has not been determined. The plants are tolerant of the cold winters and warm summers of north-central North America.

Day-Neutral Varieties

Seascape

Introduced by the University of California, Davis, California, in 1991, Seascape produces fruit that is large, moderately firm and slightly dark-red. Sensitivity to Sinbar in Ontario has not been determined. The fruit is of sufficient size and quality to be marketable in Ontario.

Selva

Introduced in 1983 from the University of California, Davis, California, Selva produces medium-red fruit that is large and firm. The plants are weakly day-neutral and only moderately productive in Ontario.

Tribute

Introduced in 1981 by the USDA, Maryland, this variety produces medium-sized, moderately firm, medium-dark red fruit. Tribute is resistant to red stele and powdery mildew and partially resistant to verticillium wilt and leaf scorch. Sensitivity to Sinbar in Ontario has not been determined.

Tristar

Introduced in 1981 by the USDA, Maryland, this variety produces a medium-sized, moderately firm, medium-dark red fruit. Tristar has smaller fruit with a better flavour than Tribute. Tristar is resistant to red stele and powdery mildew and partially resistant to verticillium wilt and leaf scorch. Sensitivity to Sinbar in Ontario has not been determined.

The following varieties were described in the previous edition of this publication, but have not been included here because they have no particular value for Ontario:

- Apollo
- Aptos
- Arking
- Atlas
- Badgerglo
- Badgervelle
- Burlington
- Canoga
- Clare
- Cornwallis
- Darrow
- Delite
- Earlidawn
- Early Midway
- Gilbert
- Guardsman
- Hecker
- Holiday
- Marlate
- OAC St. Clair
- Raritan
- Redchief
- Scott
- Tillicum
- Tyee
- Veegem
- Veeglow
- Vesper

5. Insects, Mites and Nematodes

The pests that attack strawberries will vary from year to year and from field to field. They must be properly identified and monitored to minimize the damage they cause.

Strawberry pests may be classified as major and minor pests. Major pests are usually present each year and, if not controlled, will reduce the crop substantially. Information from the OMAFRA fact sheets on the major diseases and insect pests of strawberry, which include tarnished plant bug, strawberry clipper weevil and botrytis grey mould, has been included in this publication.

Minor pests tend to be sporadic, restricted to a specific location or variety, or usually cause little damage. However, they can cause substantial damage in some situations. For each of the following pest descriptions, a control strategy is presented. Commercial growers should consult OMAFRA Publication 360, *Fruit Production Recommendations*, for the most recent list of pest control products and their appropriate use. Pesticides recommended for insect, mite and nematode control in Publication 360 are poisonous; a Grower Pesticide Certification License number is required to purchase and apply these pesticides. Follow all the precautions given on the manufacturers' labels. Check to make sure that spraying equipment has been properly calibrated to deliver the desired volume of water and rate of product per hectare. Use exact rates of the product, follow the prescribed re-entry times and the number of days between last spray and harvest.

Major Pests

Tarnished Plant Bug

Tarnished plant bug (*Lygus lineolaris*) is one of the two major pests of strawberries in Ontario. It has two to three generations per year and is a pest of over 50 crops including alfalfa, apples, broccoli, cabbage, cauliflower, celery, cucumber, peaches, raspberries, snapbeans and tobacco.

Biology

Tarnished plant bug is a "true bug" with piercing, sucking mouth parts that pierce plant tissue. It overwinters as an adult in protected areas such as leaf litter, plant debris, hedgerows and brush piles. The adults are 6–6.5 mm long, greenish or brownish, with a yellow triangular marking on the wing (Plate 20). Adults become active in early to mid-May, and females lay eggs in grasses, broadleaf weeds and strawberry plants. Egg laying occurs above 20°C, and lasts 10–31 days, during which the female lays about 5 eggs per day.

The eggs are inserted into many plant parts. They hatch into nymphs in 7–10 days. The nymphs may appear as early as the second week of May but are usually seen first during the full bloom of mid-season varieties. Nymphs undergo five instars (stages of development). The first, second and third instar nymphs are pale green and look like aphids (Plates 21–23). These stages can be differentiated from aphids by their rapid movements, robust legs and their lack of cornicles — backward-pointing structures found near the end of the aphid (Plate 24). The third instar nymphs develop distinct wing pads that later become wings. Fourth and fifth instars start to turn brown, and their wing pads lengthen (Plate 25). Nymphs develop into adults in 12–34 days. At higher temperatures, they develop more rapidly.

Adults and nymphs feed on strawberry flowers and fruit. In northeastern North America, nymphs do the most feeding and cause the most damage to June-bearing strawberry varieties. In more southern climates, the adults also cause severe damage.

Tarnished plant bugs feed on flowers from before bloom through to petal fall. They can cause strawberry flowers to die or cause fruits to be severely deformed, a condition commonly referred to as "apical seediness," "button berries" or "catfacing" (Plate 26). After petal fall, their feeding results in berries that are slightly deformed on the sides, although still possibly marketable (Plate 27).

Tarnished plant bug damage on ripe berries resembles malformations due to poor pollination. To distinguish injury from plant bugs from poor pollination, examine the size of the seeds. With tarnished plant bug damage, the seeds in the deformed area are similar in size to those in the healthy area of the fruit (Plate 28). Fruit that is poorly pollinated usually has smaller seeds in the deformed area than in the surrounding healthy areas of the fruit (Plate 29).

Tarnished plant bug is the main pest that limits the production of day-neutral strawberries. Plant bugs at all stages of development are abundant from July through September when day-neutrals flower and fruit. This provides optimum conditions for many "cat-faced" fruit to be produced.

Monitoring

Monitoring for tarnished plant bugs should start when nymphs first appear, usually around first bloom. A degree-day model can be used to predict when the first nymphs appear. The threshold temperature for plant bug activity and development is 12.4°C. Nymphs first appear after 35–40 degree-days above 12.4°C have accumulated after April 1.

Temperatures for degree-day calculations should be recorded about 10–15 cm above ground in the strawberry row. Record the daily high and low temperatures and use these to calculate the degree-day values.

Fields should be monitored every 3–4 days from the start of bloom until harvest begins. Monitor by variety or field, depending on which area is the smallest that can be sprayed separately. Keep observations for different varieties separate, because later-flowering varieties tend to have higher populations of nymphs and a higher potential risk of injury. To monitor, tap the flower or fruit clusters into a shallow dish (Plate 30). The dish should be deep enough to capture the bugs and shallow enough to see the nymphs with a hand lens. The dish should not be white or green, so that the nymphs can be easily seen. Check the dish after each tap. If tarnished plant bug nymphs are present, the cluster is infested. Tapping in wet or windy conditions will produce an under-representation of the true population of nymphs on the flowers and developing fruit. When this happens, the field should be remonitored after 1–2 days, especially if the number of infested clusters is near the threshold for control.

The economic threshold is when pest populations are high enough to cause lost sales revenue equal to or exceeding the cost of the insecticide treatment. See Table 5–1, *Determining the Economic Threshold for Tarnished Plant Bug in Strawberry*, above.

TABLE 5–1.
Determining the Economic Threshold for Tarnished Plant Bug in Strawberry

Number of Clusters Examined	Number of Nymphs Accumulated	
	Below Threshold (Do Not Treat)	Above Threshold (Treat)
20	0	4
25	1	4
30	2	4
35	3	5
40	3	5
45	4	6
50	5	6

Sequential sampling is used to determine if the tarnished plant bug population has exceeded the economic threshold. When the number of infested clusters is equal to or more than the "Above Threshold" number, apply an insecticide. If the number of infested clusters is between the "Below Threshold" and "Above Threshold" numbers, continue sampling. A minimum number of 20 clusters should be sampled randomly. If no decision can be reached at this point, keep sampling by multiples of 5 up to 50 clusters. After sampling five clusters, check to see if a decision can be made. The "Above Threshold" column in Table 5–1 is equal to a population of 0.15 nymphs per cluster. Applying an insecticide as soon as this threshold is reached will result in less than 2% severely cat-faced fruit. If insecticide applications are delayed for 3–5 days after the threshold is reached, the percentage of cat-faced fruit could increase to 5%.

This monitoring protocol was developed for June-bearing strawberries. For day-neutrals, use a sweep net to monitor adult plant bugs and continue tapping for nymphs. Both nymphs and adults cause injury. A threshold for adults plus nymphs on day-neutral strawberries has not been determined.

Control Strategy

Cultural, biological and chemical controls must be integrated to successfully manage tarnished plant bug on strawberries.

Cultural Practices

Preliminary studies reveal that some strawberry varieties may be more resistant to tarnished plant bug feeding and show less apical seediness from it (see Table 4–3, *Strawberry Variety Ratings for Resistance to Pests and Nematodes*, on page 35). Later-flowering varieties tend to have higher tarnished plant bug populations at the critical stage of flower development.

Good weed control throughout the season, in and around the strawberry field, can reduce overwintering tarnished plant bug. Preferred weed hosts for plant bugs include dandelion, chickweed, wild mint, creeping Charlie and goldenrod. Broadleaf weeds provide alternate hosts and encourage the build-up of resident tarnished plant bug populations.

Weedy ditches, fence-lines with scrub vegetation, woodlots and alfalfa fields are ideal feeding and overwintering sites for tarnished plant bug. Where possible, strawberry fields should not be established within 500 m of these.

Chemical Control

Apply an insecticide when the threshold of 0.15 nymphs per flower cluster is reached. See OMAFRA Publication 360, *Fruit Production Recommendations*, for recommended products and rates.

Pyrethroid insecticides are very toxic, wide-spectrum products that destroy beneficials and may induce two-spotted spider mite infestations. Do not use them repeatedly. Rotate pyrethroids with insecticides from other chemical groups to avoid tarnished plant bug resistance and mite problems.

Generally, recommended insecticides have enough residual action to control nymphs for 5–7 days. Shorten this interval if plant bug populations remain above the threshold after the insecticide is applied or if it rains within 2 days of the application. Usually one or two insecticide applications per season are required to control tarnished plant bug.

Strawberry Clipper Weevil

The strawberry clipper weevil (*Anthonomus signatus*) is the other major insect pest in Ontario strawberry plantings. Alternate hosts are blueberries, wild strawberry and wild and cultivated raspberries. The major damage caused by the clipper weevil takes place during egg laying.

Clipper weevil injury usually increases in older strawberry fields where resident populations can develop.

Biology

In Ontario, there is one generation of strawberry clipper weevil per year. The adult is a small, reddish-brown beetle, 3 mm long, with a pronounced snout (Plate 31). It overwinters in protected areas such as fence lines and hedgerows and under mulch.

The adults migrate into the strawberry fields when the daytime temperature is above 16°C. Recent research indicates that clipper weevils migrate about 9 metres each season. Migration starts when flower buds are visible and beginning to extend from the strawberry crown. Female clipper weevils lay single eggs inside flower buds and partially cut off the blossom stalk a few centimetres below the bud (Plate 32). The damaged bud then wilts, turns brown and dries up (Plate 33). The eggs hatch, larvae develop inside the bud for about 4 weeks, then pupate and emerge in mid-summer. After they emerge, the adult weevils feed on pollen from flowers and weeds until the fall, then seek out overwintering sites.

Adults often cut into unopened flower buds to feed on pollen a few days before egg laying and bud clipping and leave small holes in the petals and sepals (Plates 32 and 34). This activity does not usually cause fruit damage but does indicate that clipper weevils are present.

Monitoring

To monitor clipper weevil activity, count the number of clipped buds in a specific area. Begin to monitor when buds start to extend from the crown and the daytime temperatures reach 16°C. Check fields at least twice a week. Most clipper weevils will be entering the field from overwintering sites, so carefully monitor on the outer 2–3 rows of the field closest to these sites. Place a 30-cm x 60-cm wooden frame on a row and count all the clipped buds within the frame (Plate 35). Check five locations at the edge of the field. Also sample inside the field to assess whether a border spray is needed and what width would be necessary.

Historically, a threshold of 1.3 clipped buds per 2 sq ft of row was used for clipper weevil control. Recent research from New York raises the threshold to 13 clipped buds per 2 sq ft of strawberry row. Insecticides should be applied at the latter threshold. Most varieties compensate for this number of lost buds when injury occurs before the flowers open by producing larger fruit on the remaining buds. Interior rows should be checked for a resident population of clipper weevils. Fields should be re-examined for newly clipped buds 5–7 days after the first insecticide application. These buds will still be green with only a little browning. Thereafter, fields should be monitored twice a week until full flower.

Control Strategy

Cultural Practices

Good weed management is essential to control strawberry clipper weevils. Eliminate broadleaved weeds, because their pollen is the main food source for adult weevils.

Chemical Control

Apply an insecticide as soon as the threshold is reached. If damage is confined to the edges of the field, only spray the border rows. See OMAFRA Publication 360, *Fruit Production Recommendations*, for recommended products and rates.

In most situations, only one insecticide spray will be required to control strawberry clipper weevils. Fields with severe clipper weevil pressure may require a second spray, if the threshold is reached 7 days after the first one. Late clipper weevil damage is often prevented when tarnished plant bug sprays are applied.

Sporadic Insect and Mite Pests That Feed on Leaves

Spittlebug

Spittlebugs (*Philaenus spumarius* and *P.leucophthalmus*) get their name from the peculiar spit-like substance that covers the nymphs. In Ontario, spittlebug populations rarely reach damaging levels. However, spittlebugs can be an aesthetic pest in PYO fields, because customers dislike the frothy masses of spittle that the nymphs produce (Plate 36).

Spittlebug nymphs pierce the plant stems and suck plant juices. Initially, they feed at the bases of the plants, but later move up onto the new, developing foliage. Leaves can be distorted and berries stunted if the nymphs feed excessively on them. The leaves develop a crinkled and dark green appearance, which can resemble symptoms of crinkle virus. Plants recover after the spittlebug departs.

Biology

Spittlebugs overwinter as eggs inserted into the leaf bases or crown of the plant. Eggs hatch and nymphs appear in late April or early May (Plate 37). The nymphs take 5–8 weeks to mature. Adults migrate in June and return in September and October to lay their eggs at the base of plant stems.

Monitoring

Usually growers do not need to monitor for spittlebugs. Strawberry fields that are weedy or surrounded by hay fields or pastures may need to be monitored. Expect higher populations near grassy areas or where broadleaved weeds are found in adjacent vegetation.

Begin monitoring in late April or early May in southern Ontario. Check all plants in five randomly selected 2-ft x 1-ft (60-cm x 30-cm) areas per acre of strawberries every 2 weeks. Early in the season, use the same areas that are monitored for strawberry clipper weevil. Begin by looking for spittle and nymphs at the base of the plants in the crown area. Later look on the underside of young leaves as they grow. On hot, dry days, the nymphs and their spittle may be at the base of the plant. On these days, spread the plants and inspect the crowns.

PYO customers may be willing to accept about two spittlebugs per 2 sq ft without complaints. Populations above 10 spittle masses per 2 sq ft can reduce yields.

Control Strategy

Good weed management will help to control spittlebugs, because the adults are less likely to return in the fall to plantings that are free of weeds.

Usually, spittlebug populations will stay well below threshold levels when insecticides are applied to control tarnished plant bug.

Potato Leafhopper

Biology

Potato leafhoppers (*Empoasca fabae*) do not overwinter in Ontario. Migration from the southern U.S. takes place each season as wind currents and the jet stream bring weather systems northward. They often establish first in alfalfa fields and later disperse to strawberry and other crops.

Adults (Plate 38) and nymphs of the potato leafhopper feed on plant juices and reduce growth and vigour. They move into strawberry fields in June and July. Signs of leafhopper damage are plants with short petioles and small leaves that are yellow along the margins (Plates 39 and 40). The leaves are usually cupped downwards, and in severe cases, the margins of the leaves may die. Leafhoppers can infect plants with aster yellows and green petal diseases.

Monitoring

First year plantings are apparently more susceptible to potato leafhopper than older plantings. Young plantings should be monitored from late June onwards. Established plantings of susceptible varieties, such as Governor Simcoe and Settler, should be monitored from renovation to late August. Adults can be spotted by kicking or

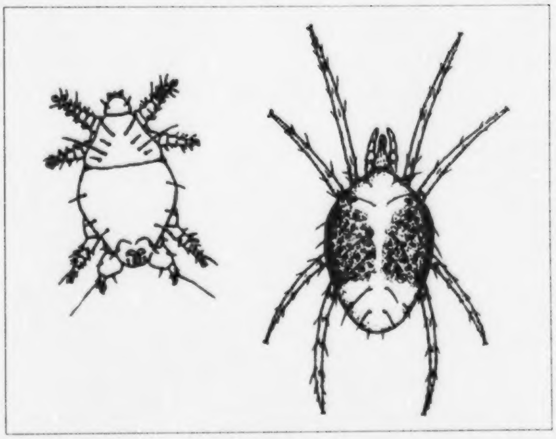


FIGURE 5–1.
Cyclamen Mite and Two-Spotted Spider Mite
Cyclamen mite (left) is considerably smaller; adult cyclamen mite can be pinkish-orange, while nymphs may be transparent. (Diagram courtesy of *Midwest Small Fruit Pest Management Handbook*)

disturbing the plants. A sweep net can be used to capture and identify the adults. The green nymphs move sideways when disturbed and are found on the undersides of the leaves (Plate 41).

Control Strategy

No threshold levels have been established. Use an insecticide when leaf symptoms occur. There are several generations of leaf hoppers each summer, and more than one insecticide application may be needed. See OMAFRA Publication 360, *Fruit Production Recommendations*, for recommended products and rates.

Cyclamen Mite

Cyclamen mite (*Phytonemus pallidus*) can drastically reduce the vigour of strawberry plantings. Infested strawberry plants are stunted, with leaves and stems twisted and distorted (Plate 42). The stems or petioles of leaves remain short. This injury is often confused with herbicide or winter injury.

Biology

Cyclamen mites are considerably smaller than two-spotted spider mites (see Figure 5–1, *Cyclamen Mite and Two-Spotted Spider Mite*, above). They cannot be seen with the naked eye or with a hand lens. The adult mites are pinkish orange, while the nymphs are fairly translucent. Eggs appear as a white mass on the mid-vein of folded leaves in the crown. Cyclamen mites feed on the growing point of the strawberry plant.

Hot, dry weather favours cyclamen mite development. Implements, clothes and other materials easily spread mites from infested to clean plants.

Monitoring

Cyclamen mites cannot be seen with a hand lens. Samples from fields where mites are suspected should be viewed under a microscope at 30–40 times magnification. Dissect the plant and examine the tiny unfolded leaves in the growing point. Older leaves may show symptoms, but mites are found only on the newest growth. Send a sample to the Pest Diagnostic and Advisory Clinic to confirm your identification the first time.

Control Strategy

Buy plants grown under the guidelines of an accredited plant propagation program to ensure clean planting stock. New plantings should be isolated as much as possible from older infested ones or wild strawberry plants. Insecticides can be applied in early spring or after renovation. High volumes of water should be used with the insecticide so that the crown and growing point are thoroughly drenched. See OMAFRA Publication 360, *Fruit Production Recommendations.*

Two-Spotted Spider Mite

In recent years, two-spotted spider mite (*Tetranychus urticae*) populations have increased in strawberry fields. This is partially because pyrethroid insecticides, which are toxic to beneficial insects, are used more frequently.

Biology

Two-spotted spider mites overwinter as adults on the undersides of strawberry leaves close to the ground. The mites are small and yellow, with two black spots on their shoulders (Plate 43). The overwintering adults are yellowish-orange.

Spider mites feed on many species of plants by sucking plant juices from the undersides of leaves. In the spring, adult mites begin feeding and reproduce continually throughout the season. As new leaves appear, the mites move to the new growth. Moderate-to-high populations of spider mites can significantly reduce plant vigour. Leaves damaged by spider mites will have a stippled or bronzed appearance (Plate 44). Damage is first seen in the drier areas of a field where spider mites are more prevalent.

Monitoring

Examine leaf samples for two-spotted spider mites just after harvest and again in mid-August. Where there has been a history of two-spotted spider mites, sample fields shortly after bloom. To sample, walk diagonally across the field, randomly picking one mature, fully expanded leaflet from every other row, until 60 leaflets have been collected.

Leaflets can be examined in the field or taken back to a laboratory and examined microscopically. Examine each leaflet for the presence of mites. Mites present on one-quarter of the leaflets corresponds to about 5 mites per leaflet. Their presence on 55% of the leaflets corresponds to 20 mites per leaflet. If all the leaflets are bagged and taken back to a laboratory to be counted, the presence/absence method cannot be used. Instead, individual mite counts for each leaflet must be recorded.

The economic threshold of two-spotted spider mite has not been determined. Some research has shown that populations as high as 20–30 mites per leaflet did not significantly affect strawberry growth or yield. In other studies, densities as low as 5 mites per leaf have caused economic injury. If plants are under stress and are growing on lighter soil types, growers may wish to use the lower threshold of 5 mites per leaf.

Control Strategy

Amblyseius fallacis, a common predatory mite in strawberry fields, is usually able to control two-spotted spider mite (Plate 45). Two-spotted spider mites are often a problem where more than two insecticides are used early in the season. Most insecticides used on strawberries are extremely toxic to *Amblyseius fallacis* and other beneficial insects.

A new strain of *Amblyseius fallacis* that is tolerant to pyrethroids has been developed by Agriculture and Agri-Food Canada. This new strain is now commercially available.

Annapolis, Bounty, Glooscap, Governor Simcoe and Kent appear to be more resistant than other varieties to spider mites (see Table 4–3, *Strawberry Variety Ratings for Resistance to Pests and Nematodes*, on page 35).

Excess nitrogen fertilizer can increase populations of two-spotted spider mite. Mowing the leaves at renovation reduces two-spotted spider mite populations by reducing their food supply.

If chemical control is required, see OMAFRA Publication 360, *Fruit Production Recommendations*, for recommended products and rates.

Miticides should be alternated to stop resistant mites developing.

Cutworms

Cutworms occasionally cause localized damage in newly planted strawberries. Several species may be involved.

Biology

Cutworms overwinter as eggs, young larvae or adults, depending on the species. The adults, sometimes known as miller moths, are stout moths that fly at night. These moths lay hundreds of eggs, mostly on plants in grassy sod or weedy fields. Cutworm larvae are greasy looking, striped, mottled, dull greyish and nearly 5 cm long when fully grown. When disturbed, they curl up to a "C" position, which is typical of most cutworm species. Cutworm larvae feed mostly in the evening, when they chew through the crowns at ground level or eat the leaves (Plate 46). During the day, they curl up and hide beneath plant debris or just below the surface of the soil. When fully mature, larvae stop feeding and pupate.

Monitoring

Inspect newly planted strawberry fields for wilting or severed plants. Most cutworm damage will occur in localized areas between planting time and mid-to-late June. When damage is observed, try to collect a few larvae to estimate their maturity. Search under loose soil beneath the plants where larvae hide. Mature larvae will be 4–5 cm long, and will feed for two to three more nights at most.

Control Strategy

Keep land free of weeds and grassy crops during late summer. When grassy sod or weedy fields are ploughed in the spring, wait at least 10 days before transplanting strawberries to starve the cutworms.

Insecticides or poisoned baits may provide some control. See OMAFRA Publication 360, *Fruit Production Recommendations*, for recommended products and rates.

Strawberry Cutworm

Older strawberry plantings may also be attacked by a species of cutworm known as the strawberry cutworm. This pest is unusual in Ontario but has caused extensive damage. The larvae of this species feed on the crown of the plant and destroy new growth.

Biology

Strawberry cutworm moths lay eggs on straw, plants and in plant debris in the strawberry field. Eggs hatch in the spring, and larvae begin feeding on newly developing leaves. The larvae bore into the base of the leaf petioles, moving from smaller to larger leaf petioles and finally to the crown. Larvae can be located by the presence of wilting leaves or the presence of dark frass in the centre of the crown. Eventually most of the crown is consumed, and flower stalks are damaged.

Monitoring

Monitor for this pest between late May and early July. There are no infestations in first-year strawberry fields, because eggs are laid in the fall. In second-year plantings, small, localized areas of damage occur. These fields should be scouted for signs of wilting or damage in a "W" pattern across the field. During the third and fourth years, populations increase in fields, and infested areas get bigger and easier to detect.

Control Strategy

Eggs are laid in the fall in existing plantings. To reduce the spread of this pest from older fields to new plantings, destroy old, infested plantings in mid-September. At that time, most eggs will be laid and destroyed when plants and crop debris are ploughed under. Control of the larvae can be obtained with an insecticide applied about the end of May, when larvae are feeding on the leaf stalks.

Strawberry Leaf Roller

There are many species of leaf rollers that feed on a variety of plants and occasionally attack strawberries. Most species of leaf roller have similar habits. The larvae roll or fold the plant leaves by means of webbing (Plate 47), wriggle backwards when disturbed and feed on plant leaves. Occasionally, larvae feed between the berry and calyx.

The strawberry leaf roller (*Ancylis comptana fragariae*) feeds only on strawberry, raspberry and blackberry, feeding on the outer layer of leaf tissue. Continuous feeding causes the leaf to turn brown and die.

Biology

Adults of the strawberry leaf roller lay eggs on strawberry leaves. Larvae change from pale green to greyish brown as they mature and reach 12–13 mm long when full-grown. The yellowish-brown pupae remain inside the folded leaf until adult moths emerge. There are two to three generations per year.

Monitoring

To monitor for strawberry leaf rollers, scout the field for webbed and damaged leaves in late May and early June, when first generation larvae are abundant, and again in July and August, when second generation larvae hatch. Sometimes newly developing leaves are webbed together before they unfold. Pay particular attention to new plantings, late in the summer. Various species of leaf roller may become a problem in strawberry fields near woods or bush. Leaf rollers feed on trees and shrubs and blow or drop into the adjacent strawberry planting. Monitor the edges of the fields during May and June.

Control Strategy

When leaf rollers are present, mow the planting immediately after harvest or plough it down.

The first generation is usually controlled by insecticides applied for tarnished plant bug. The second generation usually does not require controls.

Strawberry plants can tolerate moderate populations of leaf-feeding insects. Avoid insecticides, especially after renovation, to encourage beneficial insects and mites to build up. If an insecticide is required, see OMAFRA Publication 360, *Fruit Production Recommendations*, for recommended products and rates. Parasites and predators can reduce leaf roller numbers effectively.

Sporadic Insect Pests Attacking Roots

Root Weevils

There are over 20 species of root weevils in North America that attack strawberry. Among these, the black vine weevil *(Otiorhynchus sulcatus)*, the strawberry root weevil *(O. ovatus)* and the rough strawberry root weevil *(O. rugosostriatus)* are the most common in Ontario.

Biology

Although the adults of these three species differ in appearance, their biology is similar. Root weevils overwinter as larvae in the soil. Early in the spring, the larvae feed on the fine roots and crowns of the plant. The larvae are creamy-white or dirty-white to brown and lie in a characteristic "C" position in the soil (Plate 48). They do not have legs and are small, which distinguishes them from white grubs. Injured plants have a stunted appearance; the leaves are closely bunched and dark-blue. The fruit remains small, and the plants often die before harvest (Plate 49). In early June, the larvae pupate, and the adult weevils start to emerge. The adults feed on leaves at night and hide during the day. The notched leaves indicate their presence in the field. Within a month, eggs are laid in the soil near the plants. Peak emergence and egg-laying by adults occurs in July after harvest. The eggs hatch into small grubs that grow as they feed on the plant roots. The adults are unable to fly, so populations and damage are confined to localized areas in the field.

Monitoring

Survey fields for dead or stunted plants. Dig up affected plants and examine the soil and the root system for larvae and evidence of feeding damage. Notched leaves are an indication of adult feeding (Plate 50).

Control Strategy

Plow under old plantings as soon as possible to stop the insects from spreading to other plantings. These root-feeding insects are difficult to control chemically, and few effective products are registered for control. Insecticides used for strawberry clipper weevil should suppress root weevil populations by killing early-emerging adults and late feeding larvae. See OMAFRA Publication 360, *Fruit Production Recommendations*, for more details.

White Grub

White grub is a common pest of strawberries in Ontario. There are three species that can cause damage. The European chafer (*Rhizotrogus majalis*) is found primarily along shoreline areas of Lakes Erie and Ontario; high populations of Japanese beetle (*Popillia japonica*) are confined to the Niagara Peninsula; and the June beetle (*Phyllophaga sp.)* is found throughout Ontario.

Biology

The June beetle has a 3-year life cycle. In the first year, eggs are laid in June, and the larvae grow in the soil and feed on the roots in the top 10–12 cm of soil. They continue to feed and grow during the second year when the most severe damage is caused. The larvae overwinter in the soil. In late spring of the third year, the larvae pupate and emerge as adult beetles in June. The eggs are laid shortly thereafter. The European chafer and Japanese beetle usually complete their life cycle in 1 year.

The larvae have soft, white, C-shaped bodies with tan or brown heads and six prominent spiny legs (Plate 51). The length varies depending on species. At full maturity, the larvae range from 2 cm for Japanese beetles to 4 cm for June beetles.

Monitoring

Where plants show poor vigour or have wilted, collapsed and died, check the roots for damage and soil around the plants for grubs. First-year plantings are most susceptible to damage.

Control Strategy

Cultural Practices

Avoid planting strawberries following sod, corn, potato, strawberry and cereal-grass species. Include forage legumes and horticultural row crops in rotation with strawberry plantings or before planting strawberries to break up sod and pasture. June beetle adults tend to colonize fields with grassy and weedy areas. Keep strawberry fields and all rotational crops weed-free during the period of peak flight in May and June. Summer fallowing and frequent cultivation can also reduce grub populations by physically destroying larvae and pupae or exposing them to predators such as birds.

Chemical Control

There are no insecticides registered for white grub control on strawberries. Grass parking lots at pick-your-own operations can be a large reservoir for the build-up of grubs. These parking areas can be treated with insecticides for white grub control. For recommended products and rates, refer to OMAFRA Publication 360, *Fruit Production Recommendations.*

Sporadic Insect Pests Attacking Fruit

Slugs

Slugs(*Deroceras* and *Arion spp.*) are slimy, tear-drop-shaped, soft-bodied and legless. The grey garden slug is probably the most common species. It is mottled brown or grey and is 6–12 mm long (Plate 52).

Slugs feed on strawberry leaves and fruit, but leaf damage is insignificant unless the growing points of young plants are destroyed. If wet weather occurs during harvest and slugs are numerous, up to half of the crop can be destroyed by slugs eating holes in the fruit. Most species of slugs are active only at night, during overcast days or in the shade of a thick plant canopy. The unsightly appearance of slugs and the associated damage can deter PYO customers and increase economic losses.

Biology

Slugs have two populations: one that is active in the spring, and the other in the fall. Each population has one generation per year, which takes about 9 months to complete. Spring population slugs hatch from resting eggs in late summer, develop during fall and winter and lay eggs in the late spring. Fall population slugs hatch in late spring from eggs laid in the late fall. These larvae develop over the summer and lay eggs in the fall. Both populations hatch in response to cooler temperatures and moisture and may be active at the same time.

Monitoring

Slug injury is easy to recognize by the slimy trail left on the surface of the fruit.

Control Strategy

Cultural Practices

Slugs shelter under straw mulch in the field and can overwinter there. Slug populations will be reduced if the straw mulch and plant debris are cultivated into the soil at renovation. A second cultivation done in early fall when conditions are dry will reduce slug populations further.

Slugs do the most injury during damp, rainy seasons, but they can cause damage in dry seasons when plantings are irrigated frequently. Irrigate early in the day to allow plants to dry rapidly by nightfall.

Slug populations can be reduced by good soil drainage. Rows should be kept narrow and weed-free to allow foliage to dry rapidly. Do not over fertilize with nitrogen.

Chemical Control

In severe cases, poison baits can be spread in the field. These baits should be placed under the straw mulch between the rows to avoid contact with fruit and pickers. These baits are very attractive to dogs and poison them. Pelletized baits are easy to distribute and are preferred by most commercial growers. However, during a wet spring when slug populations are high, baits may not reduce the populations sufficiently.

Most insecticides are toxic to slugs. Therefore, in most situations, insecticide sprays applied to control tarnished plant bugs and strawberry clipper weevil will suppress slug populations. However, they will not control slugs if the plants have heavy foliage or if a thick straw mulch is present.

Strawberry Flower Thrips

Strawberry flower thrips (*Frankliniella tritici*) are an occasional pest of strawberry in Ontario. This pest can cause significant damage to fruit. The resultant bronzed and cracked fruit are unacceptable in the marketplace (Plate 53).

Biology

Strawberry flower thrips are not thought to overwinter in Ontario. Adult thrips (Plate 54) are carried by air currents from the south in the spring. Depending on the year, this migration can coincide with the bloom of strawberry. Thrips are attracted to white flowers and therefore strawberry bloom, although they will feed on most crop plants, weeds and trees.

Strawberry flower thrips are extremely small, only 1.3 mm long, cigar-shaped insects. Adult females are generally yellow to brown. Males are slightly smaller and lighter in colour. Adult thrips are weak fliers that have fringed wings that resemble a comb or feather. The immature stages are lemon yellow and wingless but can move around on the plant fairly quickly. Both adult and immature thrips hide in protected places and are more active at night. To the naked eye, they resemble small yellow threads, and a 10X–20X hand lens is needed to see them.

Thrips feed by rasping and sucking on the fruit, especially in protected places, such as under the hull and in depressions around the seeds. Rasped areas under the cap tend to crack and split open. As the fruit expands and the seeds separate, thrips feed extensively on the fruit between the seeds, which causes the entire fruit to become bronzed. As the fruit ripens or becomes heavily bronzed, the thrips migrate to other fruit, so that with a large infestation of thrips, all the fruit in a field may show some feeding damage.

Monitoring

No economic threshold has been established for control of thrips in Ontario. In New Brunswick, research has found that when there are more than two thrips per fruit when the fruit is starting to ripen, the amount of unmarketable fruit can exceed 20%.

Although thrips are not a problem most years, it is wise to monitor for this pest. There are two methods for monitoring:

1. Collect 10 flower buds in a plastic bag, seal tightly and put in sunlight. The heat will kill the thrips rapidly. Count the number of thrips. Treat if there are over 10 thrips per flower.

2. Because thrips are difficult to see, a second method is recommended: Collect a random sample of 50 fruit in 0.5 ha when the first fruit are 5–10 mm in diameter. Count the number of bronzed fruit. If five or more fruit are bronzed, then control is needed.

Control Strategy

There is no recommended chemical control for strawberry flower thrips in Ontario. Research in New Brunswick, Pennsylvania and Ohio has found that thrips populations are suppressed when controls are applied for tarnished plant bug. Because thrips are located in the protected area of the hull, good control can only be achieved with a high volume of spray delivered at high pressure.

Nematodes

Nematodes are microscopic, unsegmented roundworms. They are found worldwide in water, soil and decaying organic matter, plants and animals. Many kinds of nematodes are not harmful. Strawberry growth and development are reduced by several nematode species.

Nematode Species

In Ontario, the root-lesion nematode (*Pratylenchus* spp.) is the most common nematode pest. Occasionally root-knot (*Meloidogyne* spp.), dagger (*Xiphinema* spp.*)* and pin (*Paratylenchus* spp.) nematodes are present in strawberry fields. These nematodes attack the strawberry roots and decrease feeder-root production. Root-knot nematodes cause galls on roots. Some species cause the death of the root terminals, which results in the stunting and "blinding" of roots. Also, the wounds made by nematodes allow soil fungi that cause black root rot and verticillium wilt to enter the roots. Reduced root growth leads to reduced plant vigour and smaller or dwarfed plants with fewer runners.

Root-Lesion Nematode

Root-lesion nematodes can be found in all soils in Ontario and are most abundant in sandy soils. They move through soil pores, usually a few centimetres each year. However, they can be spread over great distances if soil is moved by erosion, tillage, wind or livestock, or if carried in the roots of plants.

Root-lesion nematodes penetrate roots slightly behind the tip. They pierce the epidermal root cells with their stylet and secrete enzymes to open entry holes in root cortical cells where they feed. The females lay their eggs in the roots or in the soil. The developing larvae go through four juvenile stages before becoming adults and complete their life cycle in 35–42 days at 18°C–30°C. They make fine reddish brown "scratches," 1.5–3.0 mm long, on new roots. When these scratches are numerous, large areas of the roots turn reddish-brown or black, and many fine lateral roots die (Plate 55). This condition resembles the symptoms of black root rot.

Root-lesion nematode populations can increase to several thousand per kilogram of soil in one growing season on preferred host plants (see Table 5–2, *Host Status for Root Lesion and Root Knot Nematodes for Selected Ontario Plants,* on page 49). These populations are most numerous in May–June and September–October each year.

Root-Knot Nematode

The root-knot nematode is rare in Ontario plantings and seldom causes injury. This nematode causes the smaller root tips to swell and roots to branch abnormally. The swollen root tips (knots or galls) are easily recognized (Plate 56). Many broadleaved plants are hosts of northern root-knot nematode, but this species does not survive on grasses and cereal grains (see Table 5–2).

Dagger and Pin Nematode

Dagger and pin nematodes inhabit the soil and do not live in root tissue. They feed by piercing the root with their mouthparts/stylets and sucking out the cell contents. Unlike the root-lesion nematode, they can thrive in clay and clay loam (fine-textured) soils as well as in sandy soils. Dagger nematode populations are generally lower than those of root-lesion. Dagger nematodes transmit many viruses, but very little is known about their potential to transmit strawberry viruses. The pin nematode reproduces much like the root-lesion nematode and can complete its life cycle at temperatures as low as 5°C. Both dagger and pin nematodes have broad host ranges. The dagger nematode tends to prefer woody-rooted plants, including weeds such as lamb's-quarters, and is often numerous around wild *Prunus* species such as chokecherry or wild labrusca grape.

Biology

Plant parasitic nematodes are closely associated with host plants for most of their lives and they tend to favour sandy or sandy-loam soils. Life cycles among nematodes are similar. All types develop from eggs and undergo a series of immature stages and molt before they become adults, when they are 0.4–1.5 mm long. Some species of nematodes spend their lives within the plant, while other species scavenge their food through root surfaces. Nematodes use a stylet to puncture cells and suck out the contents. They are so small that even when present in large numbers, they cannot be seen without a microscope. In severe infestations, they can number thousands per gram of dry root.

Monitoring

Examine the root systems of plants that show stunting or symptoms of nutrient deficiency. If you see these symptoms, take samples of roots and soil to confirm that nematodes are the problem. A diagnostic service is available at the Pest Diagnostic and Advisory Clinic, University of Guelph. Take soil samples within the row, in the root-zone of an existing strawberry field. In a new field, especially on coarse-textured soil, take soil samples the previous year to determine nematode population levels. Sample during August and September with a narrow spade or a soil sampling tube and include some feeder roots if possible. If soil conditions are hot and dry, delay sampling until September. Sample randomly at a depth of 5–30 cm, preferably in the root zone of the existing

TABLE 5–2.
Host Status for Root Lesion and Root Knot Nematodes for Selected Ontario Plants

Species	Root Lesion	Root Knot	Species	Root Lesion	Root Knot	Species	Root Lesion	Root Knot
Alfalfa	●	●	Dormoats	●	○	Purple Goat's Beard	?	●
Alsike Clover	●	●	Dotted St. John's Wort	●	●	Purslane Speedwell	?	●
Annual Daisy Fleabane	●●●	✖	Field Bindweed	○	?	Red Clover	●●	●●
Annual Sow-Thistle	●	?	Field Horsetail	○	?	Redroot Pigweed	○	●
Barley	●●	✖	Field Peppergrass	●	●	Red Top	●	✖
Beet	○	●	Fireweed	●	●	Ribgrass	?	●
Biennial Wormwood	●●●	●	Galinsoga	?	●	Rough Cinquefoil	●	●
Bird's Foot Trefoil	✖	●	Garlic Mustard	?	●	Rye	●●	✖
Bittersweet	○	●	Goldenrod	●	?	Sainfoin	✖	?
Black Medic	●●	●	Green Foxtail	?	✖	Scotch Thistle	●	?
Black Nightshade	○	?	Hairy Vetch	●	●	Shepherd's Purse	●	●
Bromegrass	●●	✖	Hybrid Henbit	○	?	Small Flowered Cranesbill	?	●
Buckwheat	●	?	Italian Rye Grass	○	✖	Sorghum	■	?
Bull Thistle	?	●	Jerusalem Artichoke	?	✖	Spinach	●	○
Cabbage	●	○	Kentucky Bluegrass	●	✖	Spotted Touch-Me-Not	○	?
Canada Fleabane	○	✖	Kidney-Leaf Buttercup	●	?	Stinkweed	○	●
Canada Thistle	●	●	Knotweed	○	●	Sudan Grass	■	?
Carrots	●	●●	Lady's Thumb	●	●	Swallowwort	?	●
Catnip	?	●	Lamb's Quarters	●	●	Sweet Clover	●	?
Cauliflower	●	○	Lettuce	●	○	Sweet Corn	●●●	✖
Celery	●	●	Low Cudweed	●	?	Tall Fescue	○	✖
Chicory	●	●	Mayweed	●	●	Tall Hedge Mustard	○	?
Clasping Henbit	●	●	Millet	○	?	Thyme-Leafed Sandwort	○	?
Common Burdock	○	●	Mint	?	●	Timothy	●●	✖
Common Chickweed	●	●	Mouse-Eared Chickweed	●●	●	Tomato	●	●
Common Dandelion	●	●	Mung Bean	?	●	Tumbling Mustard	○	●
Common Groundsel	●	●	Oats	●●	✖	Wild Buckwheat	○	●
Common Mallow	●	●	Onions	●●	○	Wild Carrot	●	●
Common Milkweed	○	✖	Orchard Grass	●●	✖	Wild Mustard	○	●
Common Motherwort	?	●	Oxalis	?	✖	Wheat	●●	✖
Common Plantain	●	●	Ox-ey Daisy	○	●	White Clover	●●	●●
Common Purslane	○	?	Peanut	○	●	White Cockle	?	●
Common Ragweed	○	✖	Perennial Rye (grain)	●	✖	White Lupine	?	●
Corn (field)	●	✖	Perennial Rye Grass	○	✖	White Sweet Clover	●●	●
Corn Gromwell	?	●	Perennial Sow-Thistle	●	●	White-Top Fleabane	●●	?
Creeping Red Fescue	●	✖	Pineapple Weed	○	?	Wormseed Mustard	○	?
Creeping Yellow Grass	●●●	?	Potato	●	●	Yellow Hawkweed	●●	●
Curled Dock	●	●	Prickly Lettuce	●	●	Yellow Rocket	○	●

Legend: ● good host ●● very good host ●●● excellent host ■ varies with cultivar
? unknown ○ poor host ✖ not a host

McKeown and Potter, *Agri-Food Research in Ontario* 1994.

TABLE 5–3.
Nematode Threshold Levels for Strawberry

Nematodes should be controlled before planting if populations exceed these numbers.

Nematode Species	Threshold Number Per Kg of Soil
Root lesion	500
Root knot	1,000
Pin	5,000
Dagger	100

crop. Collect 50 core samples per hectare and mix thoroughly in a clean container. Seal a 1-L sample of this mixed soil in a plastic bag to keep the sample from drying out and store at 5°C until submission to the clinic. If the samples are allowed to dry out, the nematodes will die, and the diagnosis will be incorrect.

The threshold numbers at which economic damage will occur differ with nematode species (see Table 5–3, *Nematode Threshold Levels for Strawberry,* above) and strawberry variety. However, specific threshold numbers for each variety strawberry are not known.

Control Strategy

Cultural Practices

Rotational Cover Crops Cover crops such as clovers and buckwheat should be excluded from strawberry rotations, as they are excellent hosts for root-lesion nematodes. If a cereal grain is to be used, wheat or barley is the best choice. Certain mustards and other crucifers, African marigolds and specific sorghum x sudan hybrids, such as Trudan 8 and Sordan 79, may effectively reduce nematode populations in the soil (see Table 5–2, *Host Status for Root Lesion and Root Knot Nematodes for Selected Ontario Plants,* on page 49 and Table 3–2, *Characteristics of Cover Crops Grown in Ontario,* on page 13).

Soil Amendments Research evidence has shown that organic amendments to soil that modify the soil carbon:nitrogen ratio to between 11:1 and 20:1 can reduce nematode populations. Such C:N ratios have been achieved experimentally using chicken manure and straw, with quantities balanced so that the final quantity of carbon (from straw) and nitrogen (from manure) was in the stated ratio range. On organic farms or where an integrated control approach is favoured, growers should consult a soils expert before using this method and should sample the soil before and after application to check the nematode populations.

Variety Selection Strawberry varieties can be resistant to root-lesion nematodes. Several varieties have been shown to be moderately resistant (see Table 4–3, *Strawberry Variety Ratings for Resistance to Pests and Nematodes,* on page 35). However, if the root-lesion nematode number exceeds 2,000/kg of soil (4X threshold), all varieties will sustain damage. No data are available on varietal resistance and tolerance to root-knot, pin and dagger nematodes.

Plant clean stock from an accredited plant propagation program. If plants show symptoms of nematodes, do not plant.

Cultivation Practices Nematode populations can build upon many weed species, so a good weed control program is essential in the year before planting and during the life of a strawberry plant (see Table 5–2, *Host Status for Root Lesion and Root Knot Nematodes for Selected Ontario Plants,* on page 49).

Fallowing and the application of Round-Up in the year prior to planting strawberries can reduce problem perennial weeds and lower nematode populations. Fallowing may ruin soil structure, deplete soil moisture and organic matter and contribute to wind erosion. Ploughing soil late in the fall, just before freezing, will leave nematodes exposed to cold and drying in winter and will reduce their numbers. These practices are best used to reduce moderate nematode numbers and used with soil nematode testing to determine their effectiveness.

Chemical Control

Soil fumigation before planting the strawberry field is the most effective method to control nematodes. Refer to Publication 360, *Fruit Production Recommendations,* for materials and rates and to the section on *Soil Fumigation* on page 13.

6. Diseases

The disease symptoms that are visible in the field reveal both the organism causing the disease (pathogen) and how the infected plant is responding to the pathogen. Sometimes strands of mycelium or hyphae, which are growth structures of fungal pathogens, can be seen. In the advanced stages of a disease, mature fruiting bodies produce spores that infect other plants. When a plant responds to an infection, the disease lesions often appear. These are often made of dead cells that have been killed by the pathogen. Often, the outer margin of a lesion is discoloured, but these cells are not dead. The plant tissue can change colour to be yellow, purple or a light, rusty brown depending on the disease and the plant part infected. Plants may also show symptoms of stress such as wilting if the pathogen blocks transport of water and nutrients to the healthy part of the plant.

Most fungal spores require water on the surface of the plant to germinate and enter the plant. These pathogens may require as little as 4 hours to over 36 hours to enter the plant, depending on the pathogen and the temperature. Once inside, the pathogen invades the plant tissue. However, visual symptoms may take several days to appear. There are many factors that may influence the way disease symptoms appear on a plant. These include the degree of resistance and the nutrient status of the host plant, the stage of plant development when infected by the pathogen and various environmental conditions.

When trying to diagnose what disease is present, it is important to know its biology and what field conditions favour its development. Note how cultural practices affect local field conditions, how the symptoms and progression of the disease change in the field, how it affects the plant and what its distribution is. Record weather conditions such as frequency, length and amount of rain, fog, heavy dews, frosts and above- or below-average temperatures. These all help to explain why a certain disease has become a problem or what the fungicide application strategy should be. For most pathogens, infection usually develops faster at warmer temperatures than cooler ones. Each pathogen has an optimal temperature for infection and spore production. Record the stage of plant growth in relation to weather events. Examine a number of plants and compare symptoms.

In order to manage diseases, the grower must be able to recognize the key symptoms of a disease, know its sources of primary inoculum and know how it is spread, how it infects and the plant's growth habit.

Most fungicides used for strawberries protect the plant and must be applied before infection occurs. Some also have locally systemic activity, i.e., they move within the plant and can also control the disease after infection has occurred but before symptoms have appeared. However, they are most effective when applied before a wet period. Once the pathogen has become well established inside the plant, symptom development of the disease cannot be stopped. This may explain why, when growers have applied a fungicide 2 or 3 days after rainy weather, disease symptoms may have still developed.

Fewer fungicides are used to control diseases in strawberries compared to other fruit crops. Strawberry breeding programs have been very successful in incorporating genes for disease resistance into many varieties. See Table 4–2, *Strawberry Variety Ratings for Resistance to Diseases,* on page 34, for disease resistance ratings for the main strawberry varieties recommended in Ontario. Management practices are also important methods to control diseases on strawberries. See Table 6–1, *Management Practices for Controlling Diseases Affecting Strawberries in Ontario,* on page 52. The appropriate crop management practices can improve disease control and reduce the need for fungicides.

Diseases Affecting Fruit

Grey Mould Fruit Rot

Grey mould fruit rot (*Botrytis cinerea*), widely known as "grey mould," is the most destructive and widespread disease of strawberries in Ontario. This disease seriously reduces the quality and shelf-life of the fruit. In cool and wet crop seasons, grey mould may appear on the fruits before they are harvested (Plate 57). However, symptoms

TABLE 6–1.
Management Practices for Controlling Diseases Affecting Strawberries in Ontario

Disease	Weed Control	Pesticide Sprays	Narrowing Rows	Variety Selection	Water Management	Summer Fallowing	Certified Transplants	Soil Fumigation	Crop Rotation	Subsoiling	Nutrient Management	Isolation	Straw Mulch	See Page
Leaf Scorch	✓	✓	✓	✓										55
Leaf Spot	✓	✓	✓	✓										56
Leaf Blight	✓	✓	✓	✓			✓							56
Powdery Mildew		✓	✓	✓										57
Angular Leaf Spot			✓	✓	✓		✓				✓	✓		57
Grey Mould	✓	✓	✓	✓	✓						✓			51
Leather Rot	✓		✓	✓	✓	✓	✓			✓			✓	53
Anthracnose			✓		✓	✓	✓	✓	✓			✓	✓	54
Red Stele		✓		✓	✓	✓	✓	✓	✓	✓				58
Verticillium Wilt				✓	✓	✓	✓	✓	✓	✓				60
Black Root Rot				✓	✓	✓		✓	✓	✓	✓			60
Viruses							✓					✓		62

usually appear during the first few days after picking. Berries that deteriorate rapidly during transportation and marketing become unsellable and if purchased, lead to consumer dissatisfaction. Effective management of grey mould is essential to maintain the confidence and satisfaction of the purchaser.

Causal Fungus and Symptoms

Grey mould is caused by the fungus *Botrytis cinerea*. The fungus is able to infect the leaves, flowers and fruits of strawberry, and often may be seen growing as a greyish, cotton-like mass on the surface of diseased tissues. Symptoms do not usually develop on green tissues, instead, the fungus stays dormant until the tissues naturally senesce. It then grows very rapidly through the tissues and mature fruits. When conditions are extremely favourable for grey mould, such as during prolonged cool and wet weather, petals may become blighted, and brown lesions may form on otherwise green calyces and fruits. Rot may occur on any part of the fruit but is most frequently found near the stem end where the calyx and stamens are attached (Plate 58). Grey mould can also be a serious problem on the crowns of strawberry transplants in cold storage.

The fungus is spread by air-borne spores. Tens of thousands of spores are produced on each square centimetre of sporulating tissue. The fungus also forms other spore bodies, but these appear to be of minor importance on strawberries in Ontario.

Botrytis attacks numerous crops and weeds, and spores produced on these alternate hosts can readily infect strawberries.

Disease Cycle

B. cinerea infects strawberry through the leaves several times during the year. These infection cycles provide the inoculum to infect flowers in the spring. The leaves are highly susceptible to infection as they are developing and become less susceptible when fully expanded. The fungus can survive for several months in green leaves and then sporulates when they die (Plate 59). Strawberry plants produce new leaves from April to October with three peaks in April–May, July and September. These leaves die mainly in June, September–October and April–May.

Dead strawberry leaves are the major source of spores that infect the flowers and fruits in spring. Other potential inoculum sources in spring include the debris of many weeds. Mummified fruits are a source of spores in fall but rarely in spring. *Botrytis* spores from dead leaves are normally dispersed by wind or splashing water. Young blossom buds and open strawberry flowers are highly susceptible to infection from these spores. Frequently, *Botrytis* spores infect strawberry fruits from adjacent stamens and, to a lesser extent, through petals and calyces. Fruit infections usually remain dormant in immature fruits but become aggressive when the fruits ripen. This latent infection is why many berries with no disease symptoms at harvest develop rot in storage.

Strawberry fruits may be infected directly more often than generally assumed. The surface of many strawberries is likely contaminated by *Botrytis* spores before harvest, and infection may subsequently occur though microscopic wounds on the fruit at the post-harvest stages.

The spores germinate and infect strawberries between 0°C and 26°C, but they do best at about 20°C. They need water to germinate and require a period of wetness that varies with temperature.

Control Strategy

Control of grey mould of strawberry cannot be accomplished by a single method. The disease can be reduced by a series of cultural practices and fungicide applications. *Botrytis* spores need water to germinate, so infections can be reduced if cultural practices are altered to eliminate persistent water films on the flowers and fruits.

Cultural Practices

Good management practices may significantly influence the microclimate within the crop canopy, enhance spray coverage and, in turn, reduce the disease.

Select a planting site with good air drainage.

Choose a tolerant variety (see Table 4–2, *Strawberry Variety Ratings for Resistance to Diseases*, on page 34). Note, however, that no strawberry variety is highly resistant to the disease.

Control weeds effectively as this reduces relative humidity and leaf wetness and increases air flow through the strawberry row. Residues of many herbaceous weeds also are sources of *Botrytis* spores.

Do not fertilize excessively, as this results in a dense, humid canopy that favours infection and softens fruit, which become infected more readily.

Irrigate between 10:00 AM and 3:00 PM with short periods of water application to allow foliage and fruits to dry out before nightfall. Continuous irrigation for longer than two hours may encourage grey mould infection.

After harvest, narrow strawberry rows to 30 cm. Remove and burn foliage residues after renovation. This breaks the leaf reinfection cycle and reduces fruit rot the following year.

Cool strawberry fruits quickly to 2°C after harvest to significantly delay the development of grey mould in and on the fruits.

Chemical Control

For recommended fungicides to control grey mould, see OMAFRA Publication 360, *Fruit Production Recommendations*, for recommended products and rates.

These fungicides are protectants and should be applied before rain. During a wet period, spores on the surface of the plant tissues absorb fungicides dissolved in the water or come into contact with the fungicide when penetrating treated plant tissue and are killed.

Apply fungicides when the strawberry tissues are most susceptible to infection. For flowers and fruit, this is between first bloom and complete petal fall. Protect the flowers continually during this period. Fungicides may also be applied under adverse wet conditions during the berry development period, especially if grey mould is observed.

Usually two to three sprays applied during the bloom period at about 5-day intervals will give reasonable control of the disease. Shorten intervals between applications to every 3–5 days if weather is wet. Application at the end of an overhead irrigation schedule may be appropriate, especially if 4 days have lapsed since the last fungicide was applied.

To ensure the sale of safe products, it is important to follow the days-to-harvest intervals as indicated on the label or in OMAFRA Publication 360, *Fruit Production Recommendations.*

Leather Rot

Leather rot is the second most important fruit disease of strawberry. Quite often, it is misdiagnosed as or grouped with losses from grey mould. It occurs sporadically, but up to 30% of the fruit may become infected. The disease not only reduces yield but can also destroy the flavour of processed products contaminated with only a few infected berries.

Causal Fungus and Symptoms

Leather rot is caused by the fungus, *Phytophthora cactorum*, which is commonly found in soil and has a wide host range. It causes fruit rot and crown rot that may or may not occur together. Fruits may be affected at all stages, from bloom to fully ripened (Plate 60). Infected portions of green berries turn brown to dark brown, and the infection expands until the entire fruit is affected

(Plate 61). Infected green fruit has a firm, leathery texture. A white fungal growth usually develops in storage after harvest and can appear on the surface of the berries in the field following periods of wet weather. Infected mature berries are usually somewhat softer than healthy fruit and are sometimes dull pink to lavender or purple. Slicing infected berries will reveal darkened inner tissues. There is also a characteristic bad odour and taste in infected fruit.

Disease Cycle

Leather rot persists in the soil as thick-walled resting spores (oospores), which can survive in a dormant state for many years. Overwintering, mummified fruit are a source of oospores. When the soil is moist or wet, some of the oospores in the soil germinate and form reproductive structures (sporangia), which release mobile, infectious spores (zoospores). These microscopic zoospores are released into the soil when it is flooded or puddled and swim to the surface using tail-like structures. A leather rot epidemic can begin when strawberry fruit become infected after lying in puddled water containing zoospores or when the puddled water is splashed onto them by rain or irrigation (Plate 62).

After this, if conditions are wet or humid, the leather rot fungus forms a white fungal growth on the surface of the infected fruit. Spores are spread through the air by wind and rain. They infect the fruit most readily if conditions remain wet for one to several hours at temperatures between 15°C and 28°C. Sporangia are produced on newly infected fruit under these wet conditions. The leather rot fungus forms oospores within infected fruit that enter the soil when the fruit decays.

Leather rot is favoured by warm weather with abundant rainfall. It can also become serious when cool weather occurs with frequent fog and morning dews.

Monitoring

No specific protocol has been established to monitor this disease. Check for symptoms in poorly drained parts of the field where water from pools can splash the fungus spores onto the fruit. A diagnostic symptom of leather rot is a characteristic putrid odour that is noticeable when infected berries are sliced or broken apart.

To test for leather rot on green berries, place a few diseased berries in a paper bag inside a plastic bag and send a sample to a diagnostic laboratory.

Control Strategy

Cultural Practices

Select a planting site with good soil and air drainage. If water lies on the surface of the soil or puddling occurs, improve drainage.

The most effective control is a thick straw mulch between the rows. This will effectively stop water from splashing the soil and moving spores from the soil to developing fruit. If a straw mulch is not applied to the planting for winter protection, it should be applied between the rows no later than the beginning of first bloom in order to protect the developing fruit.

During fruiting, only irrigate and cool the plants by evaporation between 11:00 AM and 3:00 PM, for short periods of less than 2 hours to allow the plants to dry out by nightfall. Do not apply large amounts of water at one time, to prevent the build-up of puddles and splashing of surface soil water onto the fruit. In sites with a history of leather rot, or if new infections are visible on fruit, a fungicide applied immediately before the irrigation cycle may also prove effective.

Pick fruit frequently and early in the day, as soon as plants are dry. Handle fruit with care to avoid bruising. After harvest, immediately cool to temperatures below 4°C.

In areas where leather rot is a serious problem, cull all diseased fruit and remove them from the field.

Plantings where puddling or soil compaction occurs should be subsoiled at least once per year. The best time is during the period from August to early September. This helps water drain through soil hard pans and reduces puddling between the rows.

Chemical Control

There are currently no effective chemical controls for leather rot.

Anthracnose

Anthracnose fruit rot is caused by the fungus *Colletotrichum acutatum*, which can also infect runners and plant crowns. It was once considered a southern disease, but the fungus has been spreading northward. Severe outbreaks have been reported in 1991 in Ohio and Illinois in which up to 85% of the crop was lost. Weather conditions in southern Ontario are similar to Ohio. The fruit rot has now been reported in Ontario, but economic losses have not yet been estimated.

Description

Immature and mature fruit and blossoms are susceptible to anthracnose. Disease lesions on fruit are small, sunken brown spots that develop and grow no larger than about 1.5 cm in diameter. Fruit lesions remain firm and dry (Plate 63) and develop buff to pink spore masses (Plate 64). This feature distinguishes it from grey mould, which has grey spores, and leather rot, which has white spores.

Anthracnose can overwinter on fruit and plant debris. Hot, wet weather before and during bloom through harvest are ideal conditions for anthracnose to develop.

Control Strategy

Cultural Practices

Anthracnose resistance has been incorporated into some newer varieties, but all Ontario varieties are susceptible.

Plastic mulch used in annual systems actually increases water splashing and spreads the disease more rapidly. Plan crop rotations so that fields are out of strawberry production for several years before strawberries are replanted. Fumigate infected ground at the higher rates for disease control and plant plants from an accredited nursery.

Mulch plants to prevent rain splash dispersal of the spores and remove debris from the field after renovation.

Chemical Control

Fungicides are not currently registered on strawberry in Canada for control of this disease.

Leaf Diseases

Leaf Scorch

Leaf scorch is a leaf disease that occurs worldwide. The pathogen can infect all green parts of the strawberry plant. It is most visible on leaves and calyces. Infected calyces can be further infected by grey mould, rendering the fruit unmarketable. Leaf scorch destroys leaf tissue and reduces photosynthesis. Diseased leaves (Plate 65) produce less energy for plant growth and development. Symptoms are more apparent in the fall when flower buds are being initiated (Plate 66). This leads to reduced yield in the following harvest. The fungus can halve strawberry yield, but the average annual losses from scorch are between 5–10% throughout North America.

Causal Fungus and Symptoms

Leaf scorch is caused by the fungus *Diplocarpon earlianum*. It is characterized by a number of irregular blotches, initially purplish, 1–5 mm in diameter, which expand and eventually coalesce. The centres become dark brownish and eventually give the entire leaf a reddish to brown burned or scorched appearance (Plate 67).

In its early stages, scorch is easily mistaken for leaf spot and phomopsis leaf blight. However, when the spots enlarge, they do not develop the white centres typical of the leaf spot disease.

Several isolates of *D.earlianum* have been reported. These vary in their ability to infect plants. This could explain why some strawberry varieties are more susceptible to leaf scorch and why fungicides perform inconsistently in different parts of Ontario.

Disease Cycle

Leaf scorch overwinters as mycelium and/or conidia spores on both living and dead leaves. On dead leaves, ascospores are also produced. Spores are produced from early February until June, but most are produced on overwintering strawberry leaf residues in mid-May. In Ontario, both conidia and ascospores may be initial sources of leaf scorch in the spring, and both require water to germinate and infect strawberry tissue. Spores can germinate between 5°C–30°C, if the wetting period is at least 6–9 hours. The disease develops best at 20°C–25°C. Symptoms appear within 7–9 days after infection and spores are produced within 10–14 days. The conidia produced in old lesions or on dead leaves disperse to new leaves or other plant parts and serve as the subsequent source of spores to spread the disease. Younger leaves tend to be more susceptible to infection than older leaves.

Lesions of leaf scorch on susceptible varieties tend to produce more spores than those varieties with some known resistance. There are more spores produced in older plantings because of the amount of leaf litter and the increased ability of the fungus to multiply and produce large numbers of spores.

Monitoring

Monitoring should begin in early spring to assess whether early sprays are needed. Susceptible varieties such as Kent should be checked first for disease symptoms. Middle-aged leaves should be examined during the harvest period to assess whether a protectant spray is needed after renovation. They should also be monitored from mid-August to early October for early symptoms of infection, especially with susceptible varieties.

Control Strategy

Cultural Practices

Choose varieties that are resistant or moderately resistant to leaf scorch (see Table 4–2, *Strawberry Variety Ratings for Resistance to Diseases*, on page 34).

Management practices will also help the disease. Narrow the width of the matted row to 30 cm. This encourages aeration and quick drying of the crop canopy. Irrigate in the morning or early afternoon to allow sufficient time for the crop canopy to fully dry before sunset. Select a site that has good natural air drainage.

Chemical Control

Apply one or two fungicides to susceptible varieties between early May and blooming when spore production peaks. See OMAFRA Publication No. 360, *Fruit Production Recommendations*, for recommended products and rates.

In mid-August, most leaves are intermediate and/or young, making them susceptible to leaf scorch infection. As the day- and night-time temperatures cool, sufficient heavy dews provide good conditions for infection between mid-August and the end of September. Fungicides should be applied to susceptible varieties every 14 days before visual symptoms appear between mid-August and the end of September.

Leaf Spot

Leaf spot is caused by the *Mycosphaerella fragariae*. In the early 1900s, the economic impact of the disease was so great that leaf spot was considered the most important strawberry disease. Resistant varieties have since been developed, and it has now become a minor disease.

Description and Disease Cycle

Leaf infections first appear as small, deep-purple, roundish spots, 3–6 mm in diameter, on the upper leaf surface (Plate 68). In the early stages, it is hard to distinguish between leaf spot, leaf scorch and phomopsis leaf blight. As the disease progresses, the centres of the spots turn brown, then grey and then white on older leaves (Plate 69). A definite reddish to rusty brown border surrounds the grey-necrotic centre area of the disease lesion (Plate 70). In wet years, and in the presence of abundant overwintering inoculum on diseased leaves, leaf spot may infect sepals (Plate 71), leading to secondary infection by grey mould.

The main source of inoculum is the overwintering leaf lesions. Fruiting bodies are also present on overwintered leaves but they mature very slowly, and mature ascospores are not observed until fall.

On susceptible leaves, lesions can develop at temperatures from 5°C–30°C, the optimum being 15°C–25°C. At least 12 hours of leaf wetness are needed for leaves to become infected. Lesions appear from 8–18 days after infection. Sporulation on these lesions starts about 14 days after infection and lasts for 2–3 days. Spores are splashed onto leaves by rain, and the duration and intensity of the rain are the major weather factors influencing disease development.

The susceptibility of strawberry leaves is greatly influenced by their age. At less than 7 days old, leaves are the most susceptible, thereafter susceptibility declines until 15-day-old leaves are almost completely resistant.

Monitoring

Follow monitoring protocol outlined for leaf scorch.

Control Strategy

Cultural Practices

Choose varieties that are resistant to leaf spot (see Table 4–2, *Strawberry Variety Ratings for Resistance to Diseases*, on page 34).

Chemical Control

For recommended fungicides to control leaf spot, see Publication 360, *Fruit Production Recommendations*, for recommended products and rates.

On susceptible varieties, if leaf spot was present in the planting the previous fall or if the field has a history of leaf spot, apply one or two fungicides in early spring to protect young leaves. For the highly susceptible varieties, fungicides should also be applied after renovation to protect the newly emerging leaves. Ensure thorough spray coverage of the underside of the leaves, as infection takes place through the lower leaf surface.

Leaf Blight

Leaf blight is caused by the pathogen, *Phomopsis obscurans*, also known as *Dendrophoma obscurans*.

Leaf blight sometimes appears in spring, late summer or fall in both bearing and non-bearing plantings. The major effect of leaf blight is that it destroys foliage in late summer or fall. This reduces leaf area, which may result in weakened plants and reduced yields the following year.

The economic impact of this disease has not been measured in Ontario or elsewhere.

Biology

In the early stage, reddish purple, circular spots appear on the leaves, and these early symptoms resemble leaf spot. As the spots enlarge, the central portion turns brown and is surrounded by a purplish margin. Infected areas near a major vein are often oval in shape, while older spots develop into large, characteristic, V-shaped lesions. In the later stage of leaf blight, three zones of infection may be seen on the diseased leaflet: a purple, red or yellow outer margin, which gradually shades off into the normal green leaf colour; a light-brown inner zone; and a dark-brown central zone dotted with black pycnidia (Plate 72). Calyces and ripening fruits may also be infected, but this has not been noted in Ontario. The leaf blight fungus also causes a soft fruit rot that has a characteristic light-pink, water-soaked-to-light-brown lesion. This phase of the disease is more serious in warmer climates and is not common in Ontario.

The fungus overwinters on the older leaves that remain attached to the plant. Primary infection probably occurs early in the season.

Control Strategy

Control measures for leaf spot and leaf scorch will also control leaf blight.

Powdery Mildew

Powdery mildew is caused by the pathogen *Sphaerotheca macularis fragariae* and occurs on strawberry plants in all parts of the world.

White patches of mycelium develop on the lower leaf surface that enlarge and coalesce to cover the entire lower surface. The leaf edges roll upward exposing the white, powdery fungal growth (Plate 73). On varieties that show some tolerance to the disease, the margins of the leaves may have purple-to-reddish blotches with little or no sporulation. In Ontario, infection of the flowers and fruit is not common but does occur on some varieties.

Biology

Powdery mildew overwinters as mycelium in old living leaves, and spores are produced on these leaves in the spring. These spores initiate infections on young developing leaves, and a large amount of secondary inoculum is rapidly produced.

High humidity and warm weather (15°C–27°C) are needed for powdery mildew to develop on strawberries. Early warm springs with extended periods of high relative humidity allow the disease to establish early. Wind will disperse the spores for short distances. Unlike the spores of most fungal diseases, powdery mildew spores do not need free moisture to infect their leaves. They are fragile and short-lived but can germinate 4–6 hours after landing on dry leaf surfaces in high humidity. Spore germination is suppressed by rain. Leaf symptoms are visible about 6 days later after infection.

Control Strategy

Cultural Practices

Strawberry varieties differ widely in their resistance to powdery mildew. Many possess a high degree of resistance to this disease, but none have been shown to be immune. Where mildew is a problem, choose varieties that are at least partially resistant to the disease.

Chemical Control

Leaves infected with powdery mildew after harvest have not been shown to reduce fruit yields the following year. Severe foliar infection may damage or even kill leaves, however, when foliar infections are prevented by fungicide, yields have not significantly increased. Therefore, fungicides are probably of little value for control of powdery mildew on leaves.

The varieties rated as susceptible may need one fungicide application under some field and seasonal conditions; extremely susceptible ones, no more than two. In fruiting fields, apply the fungicide after renovation. Pre-harvest sprays are usually not needed.

See Publication 360, *Fruit Production Recommendations*, for the most recent control recommendations.

Angular Leaf Spot

Angular leaf spot is caused by the bacteria *Xanthomonas fragariae* and was first detected in the U.S. in 1960. The disease has since spread to many strawberry-growing regions of the world via imported planting material. Angular leaf spot was first identified in Ontario in 1992. It is now widespread in the province, but mostly at low levels with infections on the leaves only. Fruit losses due to angular leaf spot have been minimal.

Symptoms

Angular leaf spot symptoms first appear as water-soaked areas on the lower leaf surface, which eventually enlarge to form angular spots between the leaf veins (Plate 74). The most distinguishing characteristic of this disease is that when the lower leaf surface is held up to the light, light shines through the spots, and they appear translucent. When the lower leaf surface is viewed with light shining down on it, the spots are dark green, even wet-looking. Under moist conditions, such as in the early morning, infected areas of the leaves often produce a whitish, milky exudate. When this ooze dries, it leaves a whitish, scaly film.

As the lesions coalesce and cover large areas of the leaf, they become visible on the upper leaf and appear as reddish-brown spots that become necrotic and opaque (Plate 75). During these later stages of infection, a chlorotic halo may surround the lesion and, at this stage, symptoms are difficult to distinguish from those of common leaf spot and leaf scorch. Heavily infected leaves may die if the bacteria enter the major veins. Under high disease pressure, the disease will infect the sepals and the calyx, which will turn dark brown or black (Plate 76). This symptom will reduce the fresh appearance of harvested fruits and reduce sales. The disease may also move systemically through the plant and can be isolated from plant roots, crowns, petioles, stolons and stolon-tip plantlets.

Biology

The disease overwinters in systemically infected plants and on the infected dead leaves. It can survive for extended periods in dry leaves or in infected leaves buried in the soil. Angular leaf spot is usually introduced to clean fields on infected plants without visual symptoms.

This disease only spreads in wet conditions. The bacteria are spread to uninfected leaves effectively by splashing rain and overhead irrigation. It develops best in cool weather — below 20°C during the day and around freezing at night — and with high relative humidity. Prolonged wet periods, sprinkler irrigation for frost protection and heavy spring dews favour the spread of this disease. Vigorously growing plants, over-fertilized with nitrogen, are more susceptible than plants under nutrient stress.

Control Strategy

Cultural Practices

Buy strawberry plants from an accredited plant propagator who follows provincial or state guidelines for disease control. Research is in progress to develop a fast and precise laboratory technique to detect angular leaf spot on planting material.

Strawberry varieties vary in their apparent susceptibility to angular leaf spot (see Table 4–2, *Strawberry Variety Ratings for Resistance to Diseases,* on page 34). All currently recommended varieties will develop disease under optimum conditions.

Avoid areas particularly prone to spring frosts. Select open sites with good air circulation.

Adjust irrigation practices if disease is present. Frost protection may have to be forfeited in some blocks. Irrigate only during hot periods when plants are under water stress.

Restrict the movement of people and machines from infected fields to healthy fields or areas.

Chemical Control

There are no products registered to control angular leaf spot.

Root Diseases

For a key to diagnosing strawberry root problems, see Figure 6–1, *Comparison of Seven Types of Crown and Root Damage,* on page 59.

Red Stele

Red stele caused by the soil-borne fungus *Phytophthora fragariae* was first recorded in Scotland in 1921 and has since been identified in nearly every country where strawberries are grown. In Ontario, the total acreage infested with red stele remains small. It is most common on poorly drained soils, with plantings showing symptoms after a wet spring or following a rainy autumn (Plate 77). Some strawberry varieties are much more susceptible to red stele than others.

Causal Fungus and Symptoms

Root symptoms of red stele are most pronounced from the latter part of May to the end of June. Symptoms do not usually appear in the establishment year of a planting but are delayed until the spring of the first year of fruiting. Infected plants often occur in irregular patches, often associated with areas of poor drainage. Infected plants are stunted, produce few runners and produce little or no marketable fruit. New leaves may be a dull bluish-green in colour; older leaves sometimes turn red, orange or yellow. Leaves begin to wilt when it is warm and water and nutrient demands are high, and eventually the plants wilt and die. These foliar symptoms are typical of red stele, but may also be caused by other root disorders and therefore are not diagnostic.

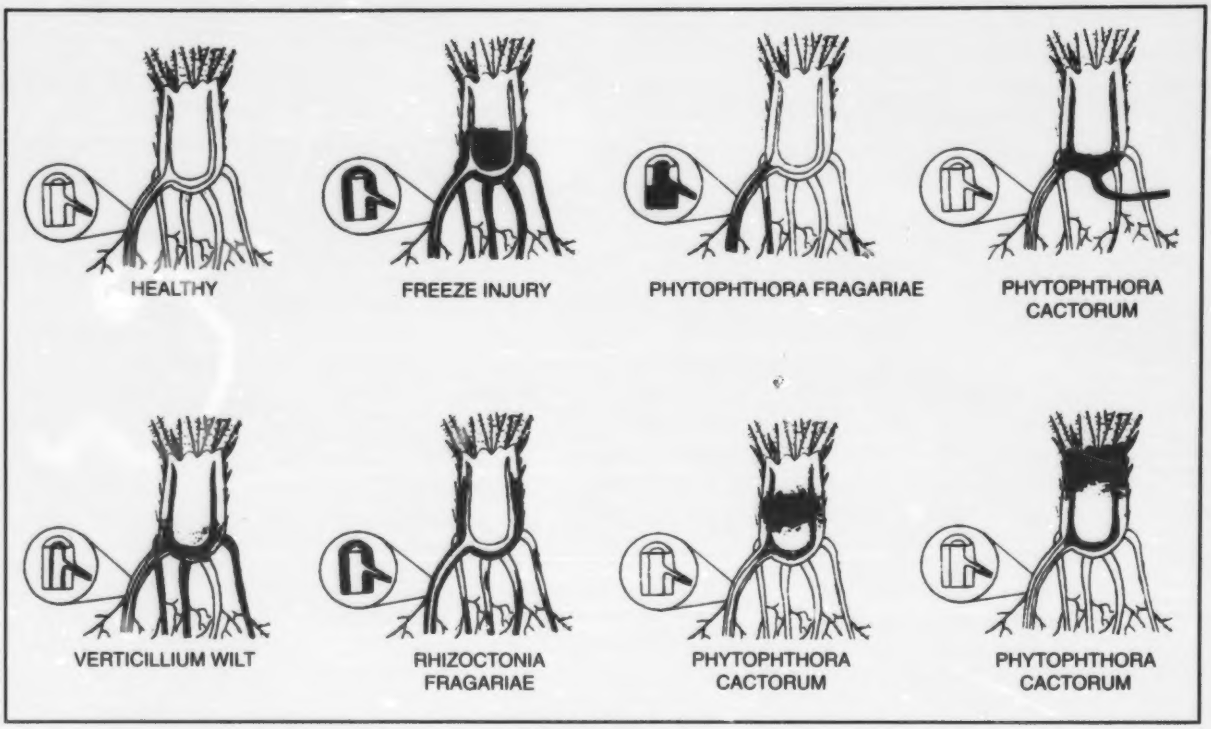


FIGURE 6–1.
Comparison of Seven Types of Crown and Root Damage
This diagram compares crown and root damage caused by freeze injury or soil-borne disease. Healthy crowns and roots appear white when first cut open. Lengthwise sections of the root and crown show different patterns of discoloration, depending on the cause of the problem. Source: *Compendium of Strawberry Diseases*, 1984, page 79. J.L. Maas, Editor.

The most reliable symptom of red stele is found within the roots. Plants with red stele usually have few fine lateral roots so the main fleshy roots have a "rat-tail" appearance. During intermediate stages of disease development, these fleshy roots will be white near the crown of the plant but will show a dark rot progressing upwards from the tips. When the white outer portion of the root just above this rotten zone is peeled off or sliced through, the root core (or stele) will appear to be dark red, hence the name red stele (Plate 78).

Disease Cycle

The fungus is introduced into new areas by infected plants or contaminated soil. Once introduced, the red stele fungus is able to persist even when strawberry plants are absent. It can be carried from an infected field to a clean field on implements and through the movement of infected soil.

During the spring, when soils are cool and have abundant free water, the fungus produces motile zoospores, which swim through soil pores filled with water and are attracted chemically to the tips of strawberry roots. They penetrate the tips of young feeder roots, and the fungus grows up the stele. As the disease develops, lateral roots die, giving the characteristic "rat-tail" appearance. During the summer, the soil becomes warm and dry, the fungus forms dormant oospores in the soil or dead root residues. Infected plants that have not totally collapsed grow new healthy roots. During the fall, when the soil becomes cool and moist again, oospores germinate and the zoospores are released into the soil when it becomes completely saturated with water. The fungus overwinters in infected roots and produces more zoospores in the spring. Zoospores also may swim to the soil surface, where they can be carried long distances in surface runoff. Zoospores are most active in soil between 7°C–15°C.

Monitoring

Monitor plants during May to early July. Gently dig up a few plants that are just beginning to wilt, taking care to preserve the root system. Check for the typical "rat-tail" appearance. Slice lengthwise through the white portion of roots just above the rotten zone and look for the characteristic red middle core of the root. Reddened steles are relatively difficult to find after harvest, because most infected roots have died and begun to decay. Samples can be sent to the Pest Diagnostic and Advisory Clinic, University of Guelph, to confirm the diagnosis.

Control Strategy

Cultural Practices

Do not plant strawberries in fields where red stele has been found. Select fields that are well drained. Light soils are less prone to the disease. Buy disease-free planting stock from an accredited nursery in a provincial plant propagation program.

If the planting has a history of red stele or is in a marginally drained site, grow resistant varieties (see Table 4–2, *Strawberry Variety Ratings for Resistance to Diseases,* on page 34). There are several races of the red stele fungus, and resistant varieties may not have resistance to all the races. Choose one that is resistant to several different races.

On heavier soils, ensure that there is good surface and systematic tile drainage. Where the land base is limited or where the soils are infected with red stele, plant strawberries on beds raised at least 25 cm high. This will raise the root system above the water table and prevent high levels of infection with red stele.

Chemical Control

For fungicides recommended to control red stele see OMAFRA Publication 360, *Fruit Production Recommendations.* Fungicides are most effective when used in combination with good soil management practices.

Verticillium Wilt

There are two species of *Verticillium*: *V. dahliae* and *V. albo-atrum*. Both attack a wide range of broadleaf plants including strawberry. *V. albo-atrum* is the more virulent species. It prefers cool soil, has short-lived resting spores (approximately 2 years) and is most prevalent in northern Ontario and cooler areas of Canada. *V. dahliae* is less virulent, has more persistent resting spores (over 10 years), prefers warmer soils and is most prevalent in southern Ontario, but is more difficult to control.

In serious outbreaks of the disease, large numbers of plants may wilt and die rapidly. The incidence of verticillium wilt is highest in strawberry fields that were previously planted with potatoes, tomatoes, peppers and eggplants. In minor outbreaks, an occasional plant or several plants scattered over the entire planting may wilt and die.

Verticillium wilt is usually more of a problem in the planting year. In new plantings, the first symptoms appear about the time runners begin to form. If conditions are wet, the disease will be most severe in late summer or fall. In fruiting plantings, the symptoms usually appear just before picking time. The fungus destroys the water-conducting tissue, so above-ground symptoms will often resemble drought stress (Plate 79). Foliar symptoms often are characteristic: the outer leaves turn brown and wilt, and the inner leaves may wilt but remain a bluish-green (Plate 80). The inner leaves eventually become stunted, turn brown and curling, wilt and die. Brownish- to bluish-black streaks or blotches may appear on the runners or petioles. New roots that grow from the infected crown are often dwarfed with blackened tips.

Monitoring

Map areas where plants have root-disease symptoms, then sample for below-ground symptoms. Choose plants that are not dead and are not totally healthy. Carefully dig up a few affected plants, preserving as much of the root system as possible. Slice the crown and roots to look for symptoms. Verticillium wilt is characterized by a brownish discolouration of the vascular system of the roots and crown (Plate 81). Field symptoms are not always diagnostic for verticillium wilt. Its presence can be confirmed by the Pest Diagnostic and Advisory Clinic, University of Guelph.

Control Strategy

Pre-plant fumigation of the site in the year before planting will control verticillium wilt. Higher rates of fumigant are needed to control verticillium wilt than are used to control nematodes.

Research on various cover crops such as marigolds and mustards is under way to assess their ability to reduce the *Verticillium* inoculum in the soil.

Some strawberry varieties are moderately tolerant to verticillium wilt (see Table 4–2, *Strawberry Variety Ratings for Resistance to Diseases,* on page 34). If soils have a history of verticillium wilt, tolerant varieties should be grown. Plant disease-free stock from an accredited nursery in a provincial plant propagation program.

Black Root Rot

In recent years, black root rot has increased in many strawberry plantings. This may be due to extreme fluctuations in weather conditions, regular pest monitoring and the repeated planting of strawberry in the same fields. Black root rot is a complex disease. The fungi *Pythium*, *Rhizoctonia* and root-lesion nematodes have been associated with plants with typical symptoms of the disease.

Description

Plants suffering from black root rot exhibit leaf symptoms that are typical of moisture and nutrient stress. These include stunted growth, wilting and the eventual collapse of the plant when fruit starts to set and as the berries mature (Plate 82). The roots of affected plants appear dark or black, and the small feeder roots are absent or dead (Plates 83 and 84). The outer root covering is blackened and decayed and strips or peels back easily, while the central stele or vascular system of the root remains white and sound (Plate 85). Eventually the whole root decays and turns rusty brown inside and black outside.

Like red stele, black root rot may occur in patches in the field. More often, black root rot extends into large areas of the field. The disease is most common in fields with a long history of strawberry production, although new plantings are sometimes affected. Black root rot symptoms usually appear once the strawberry planting begins to fruit.

The disease organisms that cause black root rot are present in many soils and tend to build up in strawberry fields as they age. These organisms are most likely to infect strawberry roots when their populations become very high or when soil conditions are unfavourable for root growth. Soil compaction is one major factor that increases the disease severity. It is often the result of poor soil structure caused by low organic matter, frequent traffic of heavy machinery, frequent cultivation and lack of crop rotation especially in soil types high in silt or clay. Drought, excessive soil moisture, excessive fertilizer application, high rates of Sinbar and continuous strawberry culture are also factors that influence this disease.

Control Strategy

Cultural Practices

Since several different organisms can cause black root rot, varieties react inconsistently to the disease. Limited data has shown that Jewel appears more tolerant than Allstar, and Honeoye is very susceptible. Black root rot is best controlled by management practices that promote optimal and healthy growth of strawberry plants.

Avoid heavy or poorly drained soils, as well as those with high fluctuating water tables.

Plant certified, disease-free stock from a reliable nursery in a provincial plant propagation program.

Subsoil plantings at renovation to break up hard pans.

Mulch plants in the late fall to prevent winter injury to the crown and roots. Mulching during the growing season between the rows reduces soil compaction caused by heavy rainfall and adds organic matter to the soil.

Irrigate only when water is needed, but during periods of drought, water frequently to maintain healthy growth. Never apply more than 4 cm of water at any one time.

Avoid replanting strawberry fields with strawberries. Plan at least a 2-year crop-rotation cycle between strawberry crops. Use crops that will add significant organic matter to the soil.

Use nitrogen fertilizer moderately to avoid poor root growth.

Rotate herbicides. Lowering the rate and frequency of Sinbar may reduce the residual levels of this product in the soil and therefore allow for more vigorous root growth.

Chemical Control

High nematode populations should be controlled (for example, by fumigation) before planting strawberries, because roots injured by nematodes are more susceptible to black root rot. Soil fumigation before planting strawberries may help to control black root rot in the short term. The fumigant kills disease-causing nematodes and soil pathogens but will also kill the microorganisms that keep populations of *Pythium* and *Rhizoctonia* in check. As a result, these disease-causing organisms can rapidly re-invade and build up in the soil. Soil fumigation may help new plantings establish, but in the long term, black root rot may not be well controlled by fumigation alone.

Slime Moulds

Description

Slime moulds are fungi that occur occasionally in strawberry fields, especially when the weather is wet. Slime moulds are creamy-white or coloured, slimy or crusty masses of fungus (Plate 86). Later fruiting structures that are marshmallow-like in texture produce powdery dry black spores. The slime mould most frequently found on strawberry plants is *Diachea leucopodia*. Slime moulds survive on decaying organic matter such as straw mulch but sometimes engulf strawberry leaves. Occasionally slime moulds appear on strawberry fruit grown in polyethylene tunnels.

Control Strategy

No control measures are needed. Slime moulds do not reproduce rapidly and do not cause economically significant losses in strawberries.

Viruses and Virus-Like Diseases

Several viruses infect strawberry plants. The viruses Mottle, Latent C, Vein banding, Crinkle, Leaf Roll, Witches' Broom and Pallidosis are examples. Infected plants of the strawberry varieties grown in Ontario usually do not show visible symptoms of virus disease. Nevertheless, the vigour and yield of these symptomless plants are usually lower than for healthy plants. This is particularly true if more than one kind of virus is present, and the planting is cropped for several years. All plants in an accredited provincial plant propagation program are derived from virus-tested mother plants. These plants have tested negative for a large number of viruses and virus-like diseases. They are the healthiest plants available.

Strawberry viruses are spread from infected plants to healthy ones mainly by aphids. Once a plant is infected, it does not recover. All plants attached to an infected plant by runners also become infected, because viruses are carried in the plant sap.

Control Strategy

Use plants from an accredited nursery in a provincial plant propagation program. Keep these plants at least 100 m from other plants.

June Yellows

June yellows is not infectious; it is an inherited characteristic. Affected young strawberry leaves show a faint streaking and mottling of green and yellow or cream in the spring (Plate 87). As the affected leaves develop, the green colour fades, and the leaves finally become golden or light yellow with little or no green. Badly affected plants are stunted, produce little or no fruit and finally die. With the arrival of hot weather, the yellow gradually disappears, and by mid-July, leaves may be a normal green. However, diseased plants show the same yellowing the following spring, and all the runner plants they produce are affected.

To prevent June yellows, grow recommended varieties and obtain plants from an accredited nursery in a provincial propagation program.

Green Petal

In plants with this virus-like disease, flower petals are dwarfed and pale green instead of white. If berries form, they are dark green, small, have prominent seeds, and do not ripen. This disease also affects clover and is spread by leafhoppers.

This disease has not become a problem in Ontario. If plants are brought into Ontario, obtain them from a recognized plant propagation program. Avoid growing strawberries near clover. Destroy plants suspected of having this disease.

Herbicide Injury

Sometimes injury from herbicides is mistaken for plant disease. Symptoms of 2,4-D injury to strawberry fruit may cause deformed fruit (Plate 88). Symptoms of Sinbar injury may resemble leaf diseases or virus (Plate 89).

7. Appendices

APPENDIX A.
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APPENDIX B.

Organizations for Berry Growers

Ontario Berry Growers Association
c/o Talisman Farm
R R # 4 Uxbridge, ON
L9P 1R4
Phone: (905) 649–2101
Fax: (905) 649–2102

Operates a berry hot line advising consumers and media of where and when they can obtain berries. Promotional materials are developed each year and provided to members at cost. Conferences and newsletters provide marketing ideas to growers.

North American Strawberry Growers Association
Contact: Erin Griebe
Executive Secretary, NASGA
2400 Beck Rd., Howell, Michigan, U.S. 48843
Tel: (517) 548-4990
Fax: (517) 548-0813
E-mail: NASGAHQ@aol.com

Takes strong leadership in providing marketing and promotion ideas to its members through conferences and newsletters. Also publishes *The Morphology and Physiology of the Strawberry* and *Advances in Strawberry Research.*

Ontario Farm Fresh Marketing Association
Contact: Bob and Donna Cobbledick
324 Lake Street, Grimsby, ON, Canada L3M 1Z4
Phone: (905) 945–9057
Fax: (905) 945–8643

Provides an idea–filled newsletter, short courses, tours, workshops and opportunities for members to share ideas and network.

APPENDIX C. Diagnostic Service

Samples for disease diagnosis, insect or weed identification, nematode counts and verticillium testing can be sent to:

Pest Diagnostic Clinic
Laboratory Services Division
University of Guelph
95 Stone Road West
Guelph Ontario, N1H 8J7
Tel (519) 767-6256
Fax (519) 767-6240
E-mail pdc@lsd.uoguelph.ca
Web site: www.uoguelph.ca/pdc

Payment must accompany samples at the time of submission.

Fee Schedule

Note: Prices current as of 1999. Subject to change.

Procedures	**Price/Sample**
Plant Diseases	
Diagnosis not requiring plating	$25
Diagnosis requiring plating	$40
Turf diagnosis	$50
Bacterial identification using Biolog®	$95
Detection of virus using Transmission Electron Microscopy	$85
Detection of virus using ELISA (turnaround time = 5 working days)	$60
Detection of virus using ELISA (RUSH: 24-hour turnaround. Available for samples received Monday through Thursday. Each additional sample is $20. ELISA tests not available for all viruses, contact clinic staff for details.)	$120 for 1–6 samples
Weed identification	$40
Insects	
Basic identification	$25
Identification requiring dissection and/or extensive keys	$40
Nematode and Verticillium Counts	**Price/Sample**
Nematodes extracted from soil (Bearman Pan Method)	$25
Nematodes extracted from roots	$60
Verticillium count	$60
SCN cyst count + egg count	$35

A minimum fee of $25 should accompany all submissions.

Payment: Please make cheque payable to the University of Guelph. Additional charges will be invoiced with the final report. VISA and Mastercard are also accepted. Please do not mail cash.

How to Sample for Nematodes

Soil

When to Sample

Soil and root samples can be taken at any time of the year that the soil is not frozen. In Ontario, nematode soil population levels are generally at their highest in May and June and again in September and October.

How to Sample Soil

Use a soil sampling tube, trowel or narrow-bladed shovel to take samples. Sample soil to a depth of 20–25 cm (8–10 in.). If the soil is bare, remove the top 2 cm (1 in.) prior to sampling. A sample should consist of 10 or more subsamples combined. Mix well. Then take a sample of 1/2–1 L (1 pint–1 quart) from this. No one sample should represent more than 2.5 ha (6.25 ac). Mix subsamples in a clean pail or plastic bag.

Sampling Pattern

If living crop plants are present in the sample area, take samples within the row and from the area of the feeder root zone (with trees, this is the drip line).

Number of Subsamples

Based on the total area sampled:

500 m^2 (5,400 ft^2)	10 subsamples
500 m^2–0.5 ha (5,400 ft^2–1.25 ac)	25 subsamples
0.5 ha–2.5 ha (1.25–6.25 ac)	50 subsamples

Roots

From small plants, sample the entire root system plus adhering soil. For large plants, dig 10–20 g (1/2–1 oz.) (fresh weight) from the feeder root zone and submit.

Problem Areas

Take soil and root samples from the margins of the problem area where the plants are still living. If possible, also take samples from healthy areas in the same field. If possible, both soil and root samples should be taken from problem and healthy areas in the same field.

Sample Handling

Soil Samples

Place in plastic bags as soon as possible after collecting.

Root Samples

Place in plastic bags and cover with moist soil from the sample area.

Storage

Store samples at 5–10°C (40–50°F) and do not expose them to direct sunlight or extreme heat or cold (freezing). Only living nematodes can be counted. Accurate counts depend on proper handling of samples.

Submitting Plant for Disease Diagnosis or Identification

Sample Submission Forms

Carefully fill in all of the categories on the form. In the space provided, draw the most obvious symptom and the pattern of the disease in the field. It is important to include the cropping history of the area for the past 3 years and this year's pesticide use records.

Choose a complete, representative sample showing early symptoms. Submit as much of the plant as is practical, including the root system, or several plants showing a range of symptoms. For turfgrass, submit a 10–15-cm^2 piece of turf, including thatch and at least 5 cm of soil. Take the sample from the outside edge of a ring or patch and include healthy and unhealthy turf, as well as the interface between. If symptoms are general, collect the sample from an area where they are of intermediate severity. Completely dead material is usually inadequate for diagnosis.

With plant specimens submitted for identification, include at least a 20–25-cm sample of the top portion of the stem with lateral buds, leaves, flowers or fruits in identifiable condition. Wrap plants in newspaper and put in a plastic bag. Tie the root system off in a separate plastic bag to avoid drying out and contamination of the leaves by soil. Do **not** add moisture, as this encourages decay in transit. Cushion specimens and pack in a sturdy box to avoid damage during shipping. Avoid leaving specimens to bake or freeze in a vehicle or in a location where they could deteriorate.

Delivery

Deliver to the Pest Diagnostic Clinic as soon as possible by first class mail or by courier at the beginning of the week.

Submitting Insect Specimens for Identification

Collecting Samples

Place dead, hard-bodied insects and spiders in vials or boxes and cushion with tissues or cotton. Place soft-bodied insects and caterpillars in vials containing alcohol. Do not use water, as this will result in rot. Do not tape insects to paper or send them loose in an envelope.

Place live insects in a container with enough plant "food" to support them during transit. Be sure to write "live" on the outside of the container.

APPENDIX D. The Metric System

Metric Units

Linear Measures (length)		
10 millimetres (mm)	=	1 centimetre (cm)
100 centimetres (cm)	=	1 metre (m)
1,000 metres	=	1 kilometre (km)

Square Measures (area)		
100 m X 100 m = 10,000 m^2	=	1 hectare (ha)
100 ha	=	1 square kilometre (km^2)

Cubic Measures (volume)		
Dry Measure		
1,000 cubic millimetres (mm^3)	=	1 cubic centimetre (cm^3)
1,000,000 cm^3	=	1 cubic metre (m^3)
Liquid Measure		
1,000 millilitres (mL)	=	1 litre (L)
100 L	=	1 hectolitre (hL)

Weight-Volume Equivalents (for water)		
(1.00 kg) 1,000 grams	=	1 litre (1.00 L)
(0.50 kg) 500 g	=	500 mL (0.50 L)
(0.10 kg) 100 g	=	100 mL (0.10 L)
(0.01 kg) 10 g	=	10 mL (0.01 L)
(0.001 kg) 1 g	=	1 mL (0.001 L)

Weight Measures		
1,000 milligrams (mg)	=	1 gram (g)
1,000 g	=	1 kilogram (kg)
1,000 kg	=	1 tonne (t)
1 mg/kg	=	1 part per million (ppm)

Dry–Liquid Equivalents		
1 cm^3	=	1 mL
1 m^3	=	1000 L

Application Rate Conversions

Metric to Imperial (Approximate)		
litres per hectare x 0.09	=	gallons per acre
litres per hectare x 0.36	=	quarts per acre
litres per hectare x 0.71	=	pints per acre
millilitres per hectare x 0.015	=	fluid ounces per acre
grams per hectare x 0.015	=	ounces per acre
kilograms per hectare x 0.89	=	pounds per acre
tonnes per hectare x 0.45	=	tons per acre

Imperial to Metric (Approximate)		
gallons per acre x 11.23	=	litres per hectare (L/ha)
quarts per acre x 2.8	=	litres per hectare (L/ha)
pints per acre x 1.4	=	litres per hectare (L/ha)
fluid ounces per acre x 70	=	millilitres per hectare (mL/ha)
tons per acre x 2.24	=	tonnes per hectare (t/ha)
pounds per acre x 1.12	=	kilograms per hectare (kg/ha)
ounces per acre x 70	=	grams per hectare (g/ha)

Liquid Equivalents

Litres/Hectare		*Approximate Gallons/Acre*
50	=	5
100	=	10
150	=	15
200	=	20
250	=	25
300	=	30

Dry Weight Equivalents

Grams or Kilograms / Hectare		*Ounces or Pounds /Acre*
100 grams	=	$1^{1}/_{2}$ ounces
200 grams	=	3 ounces
300 grams	=	$4^{1}/_{4}$ ounces
500 grams	=	7 ounces
700 grams	=	10 ounces
1.10 kilograms	=	1 pound
1.50 kilograms	=	$1^{1}/_{4}$ pounds
2.00 kilograms	=	$1^{3}/_{4}$ pounds
2.50 kilograms	=	$2^{1}/_{4}$ pounds
3.25 kilograms	=	3 pounds
4.00 kilograms	=	$3^{1}/_{2}$ pounds
5.00 kilograms	=	$4^{1}/_{2}$ pounds
6.00 kilograms	=	$5^{1}/_{4}$ pounds
7.50 kilograms	=	$6^{3}/_{4}$ pounds
9.00 kilograms	=	8 pounds
11.00 kilograms	=	10 pounds
13.00 kilograms	=	$11^{1}/_{2}$ pounds
15.0 kilograms	=	$13^{1}/_{2}$ pounds

Metric Conversions		
5 mL	=	1 tsp
15 mL	=	1 tbsp
28.5 mL	=	1 fl. oz

Conversion Tables — Metric to Imperial

Length

1 millimetre (mm) = 0.04 inch
1 centimetre (cm) = 0.40 inch
1 metre (m) = 39.40 inches
1 metre (m) = 3.28 feet
1 metre (m) = 1.09 yards
1 kilometre (km) = 0.62 mile

Area

1 square centimetre (cm^2) = 0.16 square inch
1 square metre (m^2) = 10.77 square feet
1 square metre (m^2) = 1.20 square yards
1 square kilometre (km^2) = 0.39 square mile
1 hectare (ha) = 107,636 square feet
1 hectare (ha) = 2.5 acres

Volume (dry)

1 cubic centimetre (cm^3) = 0.061 cubic inch
1 cubic metre (m^3) = 1.31 cubic yards
1 cubic metre (m^3) = 35.31 cubic feet
1,000 cubic metres (m^3) = 0.81 acre-foot
1 hectolitre (hL) = 2.8 bushels

Volume (liquid)

1 millilitre (mL) = 0.035 fluid ounce
1 litre (L) = 1.76 pints
1 litre (L) = 0.88 quart
1 litre (L) = 0.22 gallon (Imp.)
1 litre (L) = 0.26 gallon (U.S.)

Weight

1 gram (g) = 0.035 ounce
1 kilogram (kg) = 2.21 pounds
1 tonne (t) = 1.10 short tons
1 tonne (t) = 2,205 pounds

Pressure

1 kilopascal (kPa) = 0.15 pounds/in^2

Speed

1 metre per second = 3.28 feet per second
1 metre per second = 2.24 miles per hour
1 kilometre per hour = 0.62 mile per hour

Temperature

°F = (°C X $^9/_5$) + 32

Conversion Tables — Imperial to Metric

Length

1 inch = 2.54 cm
1 foot = 0.30 m
1 yard = 0.91 m
1 mile = 1.61 km

Area

1 square foot = 0.09 m^2
1 square yard = 0.84 m^2
1 acre = 0.40 ha

Volume (dry)

1 cubic yard = 0.76 m^3
1 bushel = 36.37 L

Volume (liquid)

1 fluid ounce (Imp.) = 28.41 mL
1 pint (Imp.) = 0.57 L
1 gallon (Imp.) = 4.55 L
1 gallon (U.S.) = 3.79 L

Weight

1 ounce = 28.35 g
1 pound = 453.6 g
1 ton = 0.91 tonne

Pressure

1 pound per square inch = 6.90 kPa

Temperature

°C = (°F – 32) x $^5/_9$

Abbreviations

% = per cent (by weight)
ai = active ingredient
AP = agricultural powder
cm = centimetre
cm^2 = square centimetre
DG = dispersible granular
DP = dispersible powder
E = emulsifiable
e.g. = for example
EC = emulsifiable concentrate
F = flowable
g = gram
Gr = granules, granular
ha = hectare
kg = kilogram

km/h = kilometres per hour
kPa = kilopascal
L = litre
m = metre
m/s = metres per second
m^2 = square metre
mL = millilitre
mm = millimetre
SC = sprayable concentrate
SP = soluble powder
t = tonne
W = wettable (powder)
WDG = water dispersible granular
WP = wettable powder
km/h = kilometres per hour

Colour Plates

PLATE 1. A busy pick-your-own strawberry operation. In this aerial view, note the central fenced-in parking lot with the fields surrounding the lot. Access to the fields is through one entrance with a weigh-station to check customers in and out of the field.

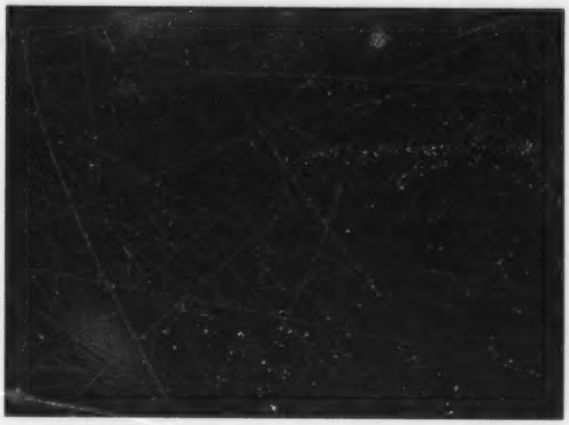

PLATE 2. Oilseed radish cover crop grown the year before planting strawberries to supply additional organic matter to the soil.

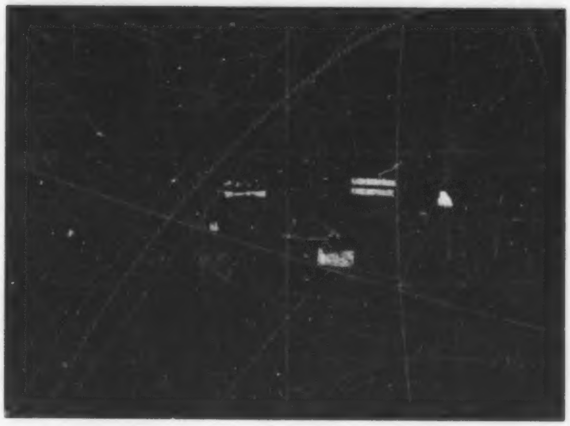

PLATE 3. Planting strawberries in early spring.

PLATE 4. Use plants like the one on the left. It has an abundance of healthy roots and a large crown. Avoid using plants with black roots, like the two centre plants. The plant on the right is too small to make good growth.

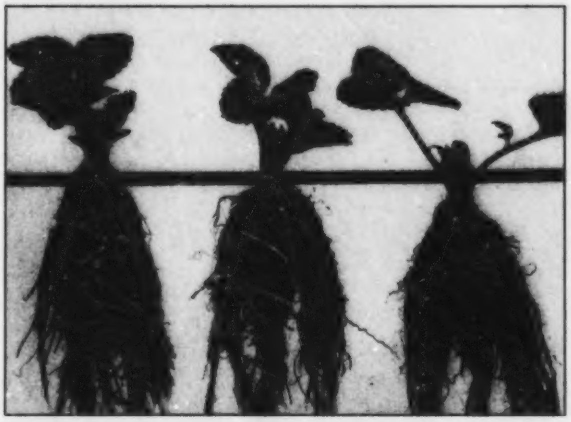

PLATE 5. Plants should be set so that the midpoint of the crown is level with the soil surface. The centre plant is set correctly, the left plant too shallow, and the right one too deep. The top of the solid line represents the soil surface.

PLATE 6. Well-mulched strawberry rows. In winter, the mulch protects the plants from injury from low and fluctuating temperatures. In summer, placed between the rows, it conserves moisture and keeps the fruit clean.

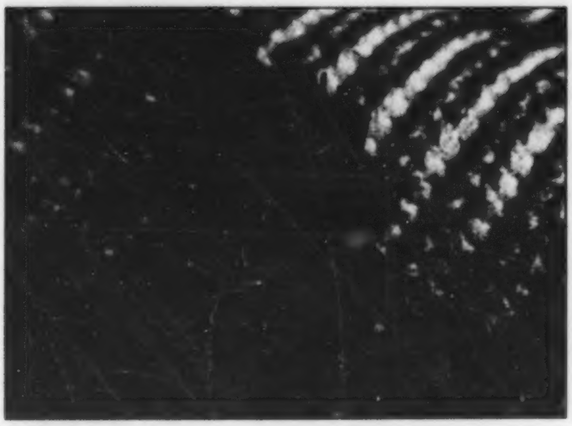

PLATE 7. Strawberry crowns cut lengthwise to show internal browning from winter injury.

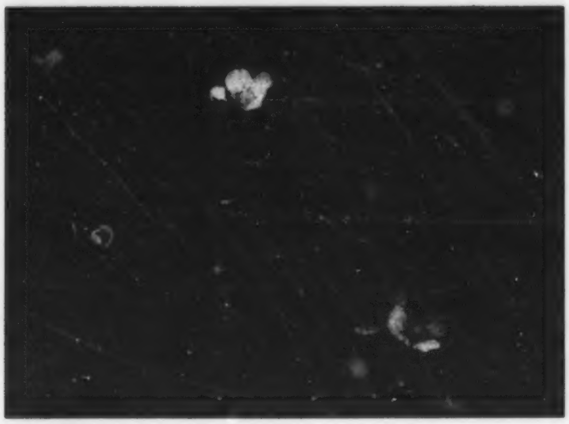

PLATE 8. Honeybees improve pollination of strawberries.

PLATE 9. Self-propelled strawberry harvester. This harvester cuts all the above-ground parts of the plant in a once-over harvest and then separates the fruit and stems from the leaves.

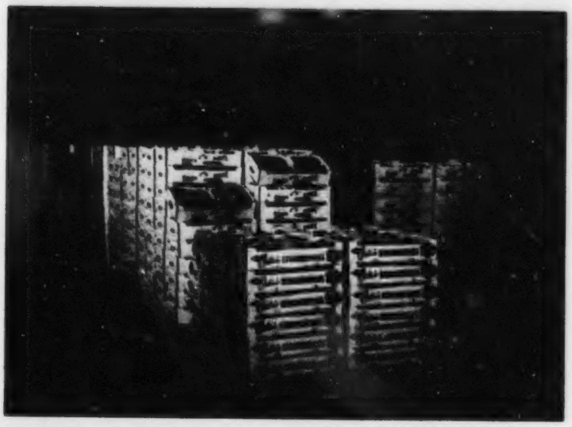

PLATE 10. Berries stacked in a cold storage do not cool rapidly. These berries will take more than 6 hours to cool from 21°C to 4°C.

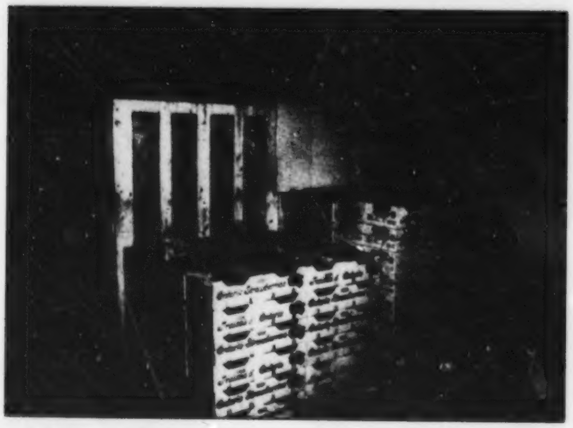

PLATE 11. A forced-air cooling unit designed to handle a large number of pallets of strawberries. The top and the ends of the pallets are covered with reinforced plastic. The fan draws cold air through the sides of the pallets into the central tunnel, absorbing heat from the strawberries.

PLATE 12. Renovated strawberry field after plants have been mowed, rows narrowed and subsoiling complete.

PLATE 13. A rototiller is effective for narrowing rows at renovation. The centre blades have been moved apart, and some cutting blades have been removed. Shields keep soil from covering plants.

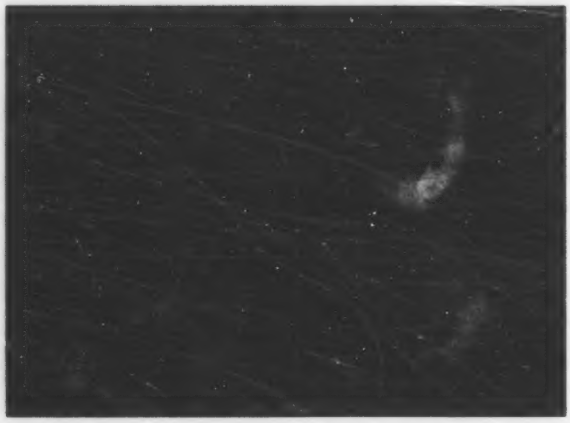

PLATE 14. The two blossoms on the right have been injured by frost. Note that the pistils (female parts) are black and dead while the stamens (male parts) and the rest of the flower show no injury.

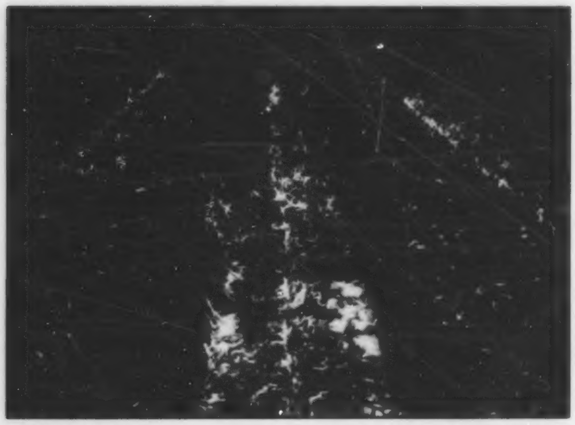

PLATE 15. An example of plasticulture in Ontario. Dormant strawberry plants were planted in early July. The beds on the far left were planted in September with plug plants as a comparison. Photo taken in late September.

PLATE 16. Solid bed planting of strawberries, grown for mechanical harvest.

PLATE 17. Spun-bonded floating row cover applied in early spring to strawberry plants.

PLATE 18. Strawberry production in a greenhouse in The Netherlands. Plants are grown in peat bags with the drip irrigation pipe and the supplemental heating pipe hanging below.

PLATE 19. Day-neutral strawberries grown on raised beds covered in plastic. Trickle irrigation tape is placed under the plastic before planting.

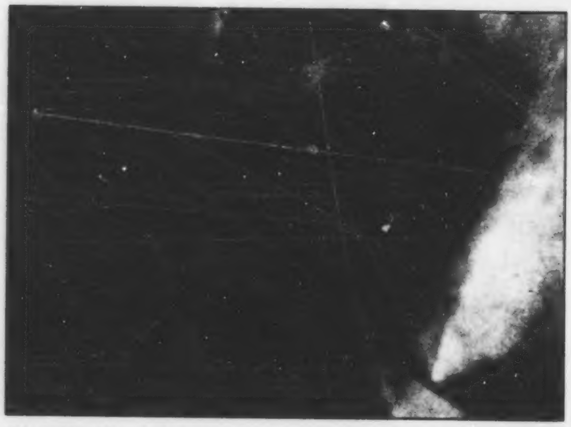

PLATE 20. Adult tarnished plant bug (TPB). Note the characteristic yellow triangle on its back.

PLATE 21. First instar TPB nymph on a strawberry flower. Note the robust rear legs, narrow body and long antennae.

PLATE 22. Second instar TPB nymph. Note one black spot on the third segment or abdomen section. Nymphs move rapidly across saucer.

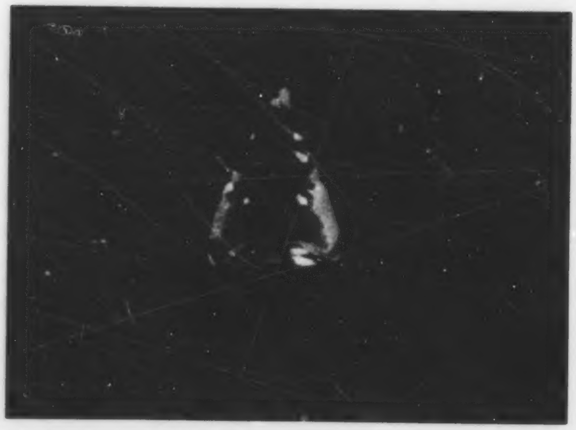

PLATE 23. Third instar TPB nymph. Note five black spots on thorax and abdomen, and wing-pad beginning to appear on thorax.

PLATE 24. Aphid on strawberry can be differentiated from TPB nymphs by its cornicles (tube-like structures on the back end). Aphids move more slowly.

PLATE 25. Fifth instar TPB nymph. Note wing-pads are more pronounced and exoskeleton is beginning to darken.

PLATE 26. Apical seediness or cat-facing of fruit caused by early feeding of TPB.

PLATE 27. Slight deformation of fruit caused by feeding of TPB during green fruit phase.

PLATE 28. Close-up of slight deformation of fruit caused by TPB. Note that the seeds are similar in size to the healthy part of the berry.

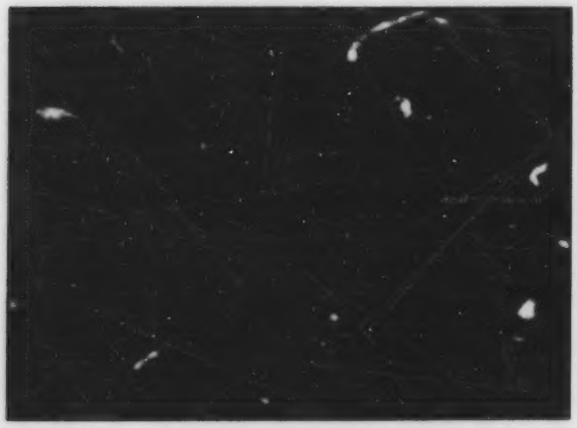

PLATE 29. Close-up of slightly deformed fruit caused by poor pollination. Note the seeds in the deformed part of the fruit are smaller than the healthy part of the berry.

PLATE 30. Monitoring for TPB by tapping flower or fruit clusters into a shallow pan.

PLATE 31. Adult strawberry clipper weevil on strawberry blossom. Colour can vary from medium to dark brown on back. Note long curved snout.

(Photo credit: Cornell University)

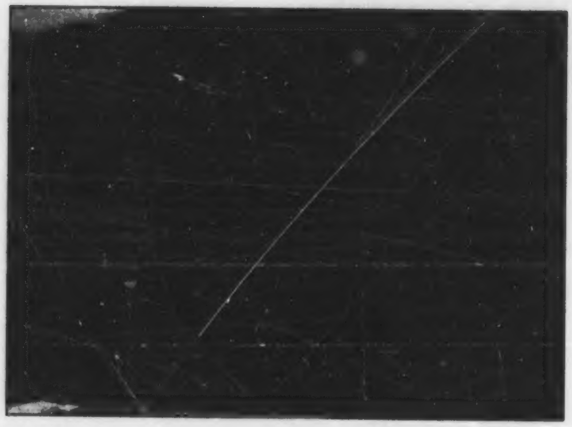

PLATE 32. Strawberry clipper weevil injury. Close-up picture of recently clipped bud. Note feeding on sepals of bud.

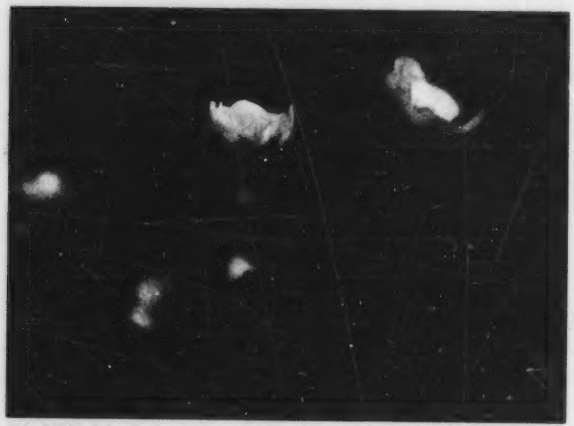

PLATE 33. Dried-up clipped bud damaged by strawberry clipper weevil. This bud has been clipped for a few days.

PLATE 34. Holes in petals from pollen feeding by strawberry clipper weevil just prior to flower opening.

(Photo credit: Cornell University)

PLATE 35. Monitoring for buds clipped by strawberry clipper weevil.

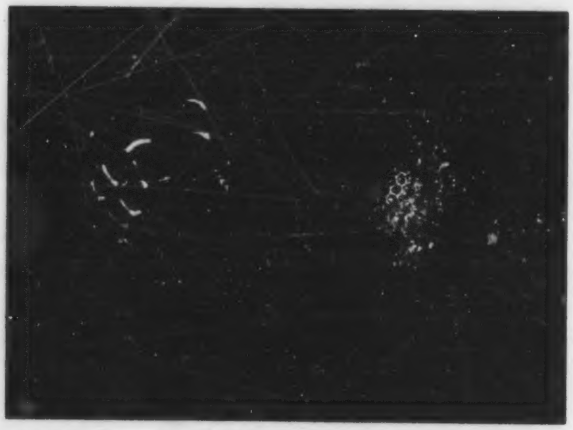

PLATE 36. Spittle produced by spittlebug nymphs in crevice where petioles meet.

(Photo credit: Cornell University)

PLATE 37. Spittlebug nymphs and spittle in protected area of developing flower bud cluster.

PLATE 38. Potato leafhopper adult.
(Photo credit: Don Hamilton, University of Guelph)

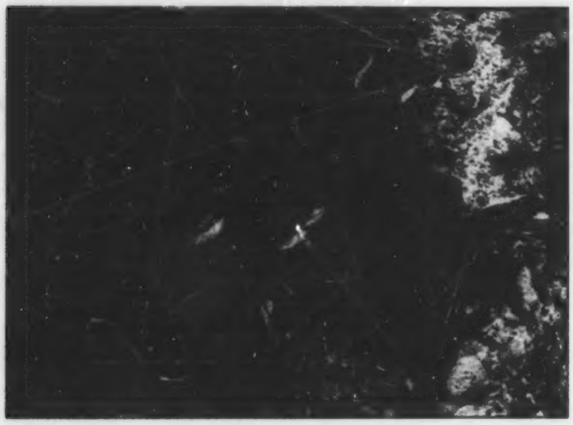

PLATE 39. Injury to strawberry leaves from potato leafhopper. Note tip burning, cupping of leaf, with yellowing chlorotic areas along margins.

PLATE 40. Damage of mother and daughter plants from potato leafhopper. Monitor new plantings because they are more susceptible than older plantings.

PLATE 41. Most potato leafhopper feeding occurs on underside of the leaf. Monitor for nymphs and adults by slowly turning over and examining underside of leaves.

PLATE 42. Strawberry plants with severe infestation of cyclamen mite. Note severe curling and stunting of leaves.

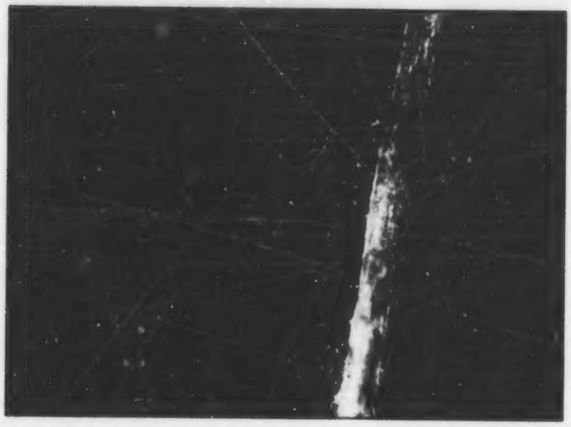

PLATE 43. Adult two-spotted spider mite (TSSM) on left with egg, right of vein.

(Photo credit: Don Marshall, Agriculture and Agri-Food Canada, Vineland).

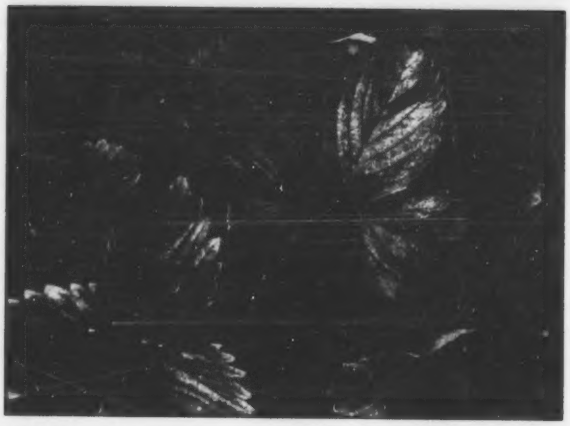

PLATE 44. Heavy infestation of TSSM causing bronzing of strawberry leaves.

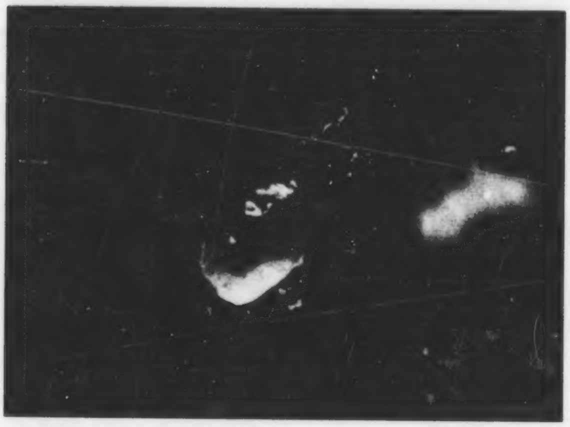

PLATE 45. *Amblyseius fallacis*, Ontario's most important mite predator in strawberry.

(Photo credit: Don Marshall, Agriculture and Agri-Food Canada, Vineland).

PLATE 46. Cutworm on leaf showing characteristic feeding injury. Most larval feeding occurs during the night.

PLATE 47. Strawberry leafroller: note feeding, rolling and webbing of leaf by leafroller.

PLATE 48. Larva of root weevil species. Key identification feature: no visible legs.

(Photo credit: Cornell University)

PLATE 49. Root weevil feeding on roots causes strawberry plants to collapse and die.

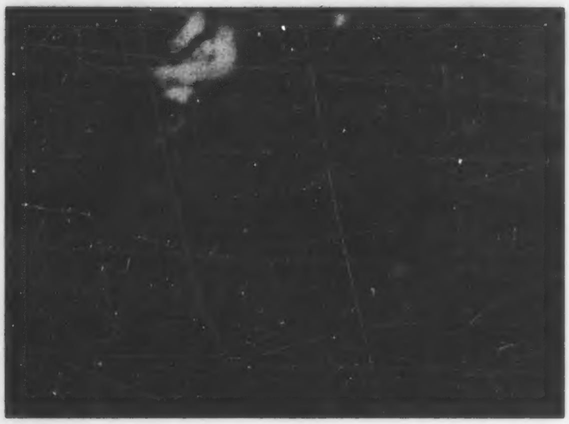

PLATE 50. Notch-like feeding on leaves by adult root weevil.

PLATE 51. Larva of white grub (size of grub depends on species and stage of development). Key identification feature: visible legs.

PLATE 52. Slug feeding on fruit. Note characteristic slime trail on leaves and fruit.

PLATE 53. Strawberry fruit exhibiting thrip damage: rasping-like abrasive damage and discolouration on surface of fruit.

PLATE 54. Adult Eastern flower thrip.
(Photo credit: K. Lynch, New Brunswick Agriculture)

PLATE 55. Root-lesion nematode damage to strawberry roots.

PLATE 56. Damage symptomatic of root-knot nematode. *(Photo credit: G. Smart, Compendium of Strawberry Diseases 1984)*

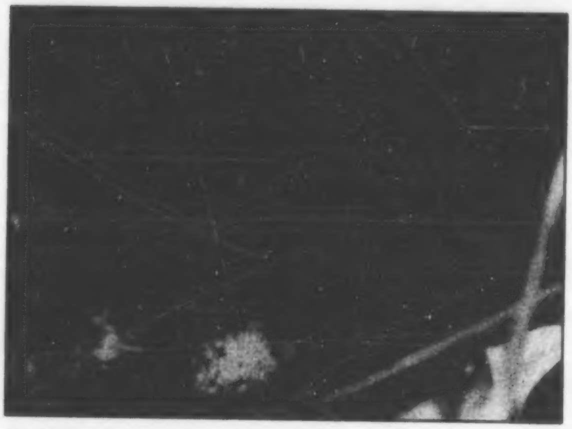

PLATE 57. Grey mould (*Botrytis*) infection with gray sporulation on ripened fruit before harvest. *(Photo credit: J. Sutton and G. Peng, University of Guelph)*

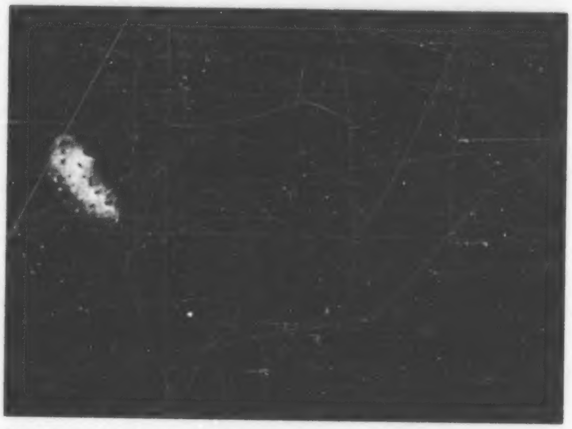

PLATE 58. Characteristic "stem end" grey mould infection near calyx on both green and ripening fruit.

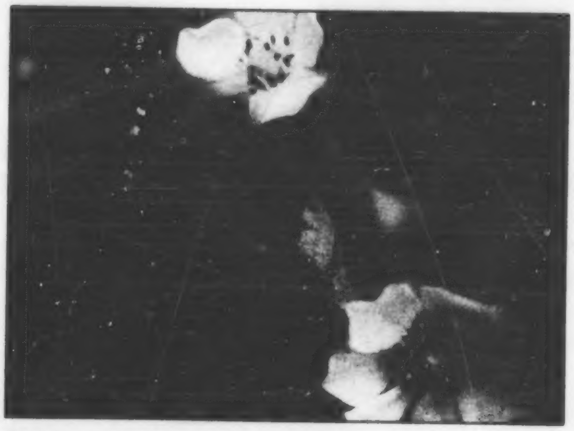

PLATE 59. Sporulation of *Botrytis* on dying leaf. Major source of disease during the bloom period. *(Photo credit: J. Sutton and G. Peng, University of Guelph)*

PLATE 60. Leather rot can attack small, large and ripening fruit. Note tough brown appearance of infected green fruit.

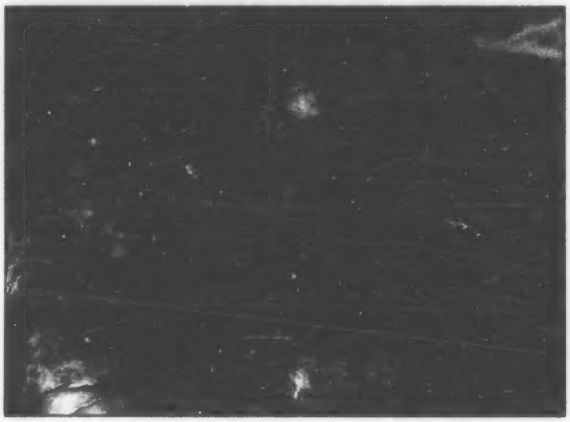

PLATE 61. Leather rot lesion expanding over fruit.

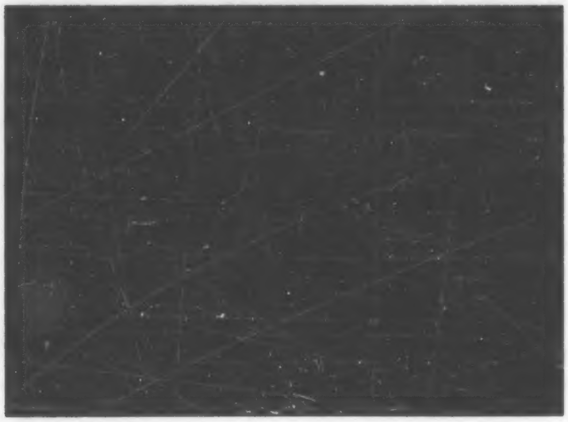

PLATE 62. Ideal conditions for the spread of leather rot — flooding and pooling/splashing of water onto fruit.

PLATE 63. Characteristic pink spore masses can occur on the surface of anthracnose lesion in humid conditions.

(Photo credit: M. Ellis, Ohio State University)

PLATE 64. Close-up of sunken anthracnose lesion on fruit.

(Photo credit: M. Ellis, Ohio State University)

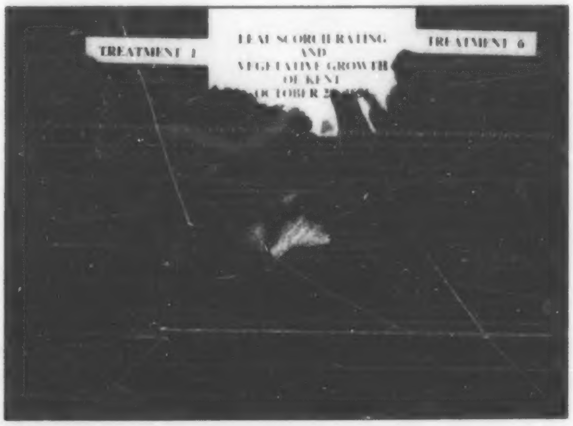
TREATMENT 1
LEAF SCORCH RATING
AND
VEGETATIVE GROWTH
OF KENT
OCTOBER
TREATMENT 6

PLATE 65. Leaf scorch infection can cause low vigor, stunt plants and affect overall yield. Treatment 1 is a healthy plant without leaf scorch and treatment 6 was heavily infected.

(Photo credit: A. Sullivan, University of Guelph)

LEAF SCORCH RATING
TREATMENT 6
KENT
PLANTED MAY 29 1992
OCTOBER 30 1992

PLATE 66. Severe, advanced infection of leaf scorch in the field in late fall.

(Photo credit: A. Sullivan, University of Guelph)

PLATE 67. Leaf scorch symptoms on strawberry leaves. Note reddish-purple lesions coalescing as disease advances.

PLATE 68. Purple-brown leaf spot symptoms on strawberry leaves. *(Photo credit: O. Carisse, Agriculture and Agri-Food Canada, St. Jean)*

PLATE 69. Advanced symptoms of strawberry leaf spot. Note grayish-brown centres with purple margins.

PLATE 70. Close-up of leaf spot lesion on leaf. *(Photo credit: O. Carisse, Agriculture and Agri-Food Canada, St. Jean)*

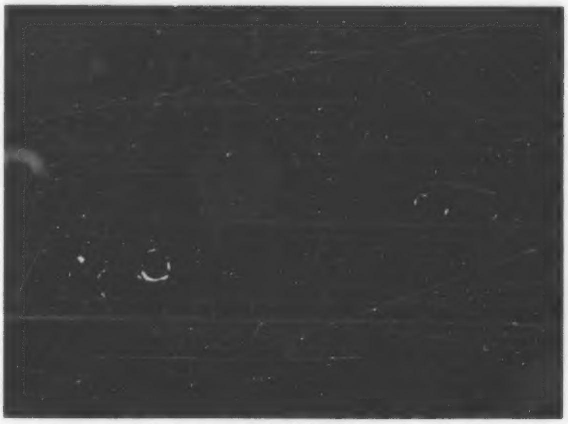

PLATE 71. Leaf spot lesions on sepals of fruit *(Photo credit: O. Carisse, Agriculture and Agri-Food Canada, St. Jean)*

PLATE 72. Advanced mature lesions of leaf blight. Note large, "V-Shaped" lesions between main veins and extending to margins of leaf.

PLATE 73. Powdery mildew causing leaves to cup upwards with white sporulation of fungus on the lower leaf surface.

PLATE 74. Early symptoms of angular leaf spot: water-soaked lesions on the underside of the leaf.

PLATE 75. Late symptoms of angular leaf spot: older lesions visible on the upper leaf surface appear as reddish-brown spots, which become necrotic and opaque.

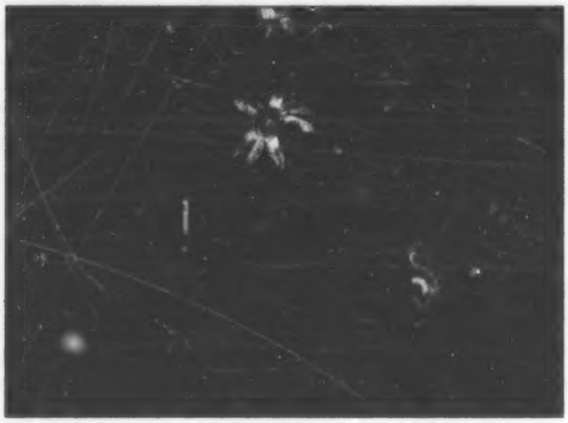

PLATE 76. Angular leaf spot symptoms on sepals or calyx of strawberry fruit.

PLATE 77. Infection of plants by red stele in low areas of the field.

PLATE 78. Monitoring for red stele in the field by dissecting roots when soil temperatures are cool.

PLATE 79. Strawberry plants show symptoms of verticillium wilt.

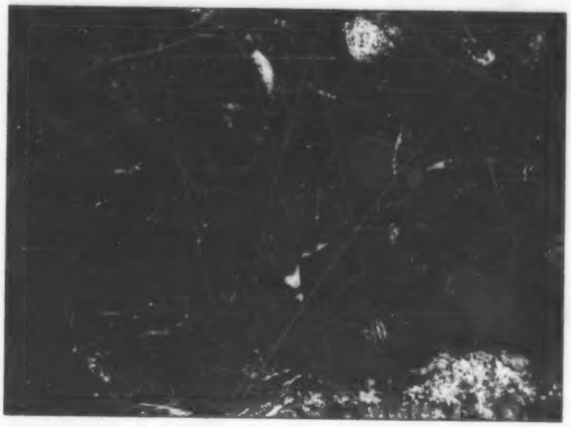

PLATE 80. Daughter plants infected with verticillium wilt collapse in year of planting.

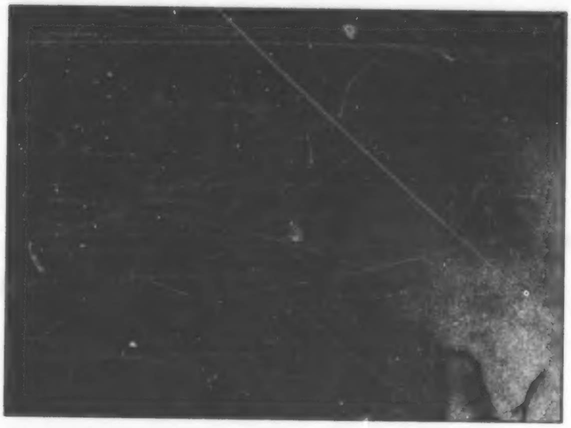

PLATE 81. Vascular discolouration of strawberry crown due to infection by verticillium wilt.

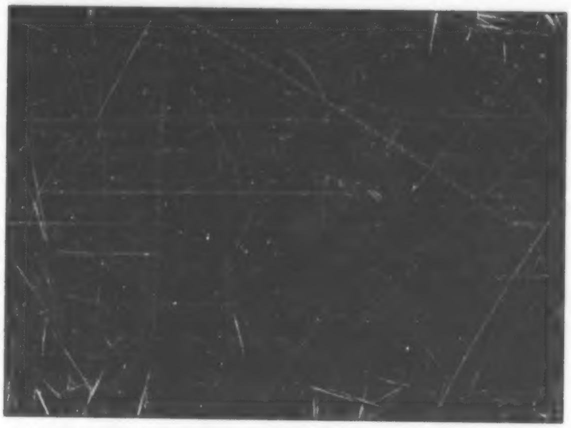

PLATE 82. Black root rot infection causing strawberry plant to collapse just prior to harvest under drought conditions.

PLATE 83. Poor lateral root development caused by black root rot.

PLATE 84. Healthy plant with extensive root system. (Compare to roots infected with black root rot.)

PLATE 85. Strawberry plants infected with black root rot have healthy crowns with dying black roots.

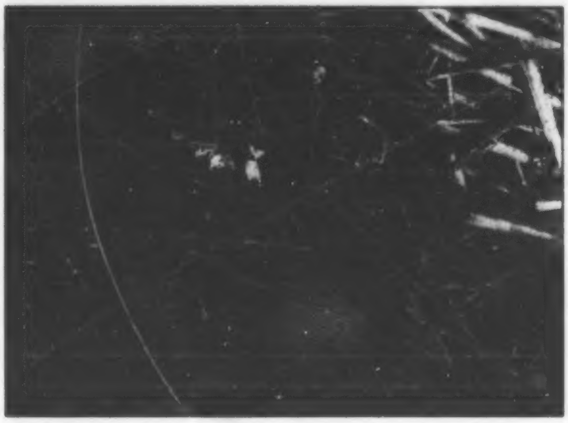

PLATE 86. Slime mould on strawberry leaves.

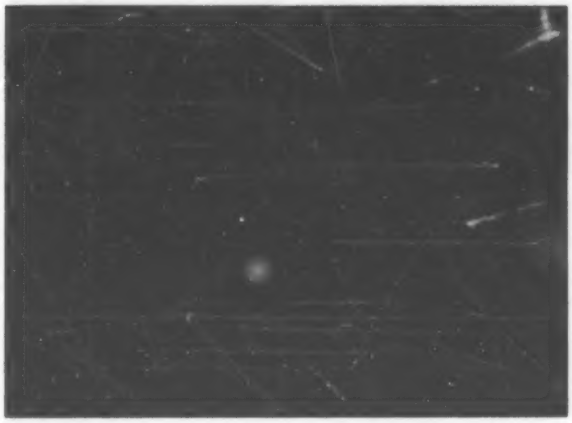

PLATE 87. Faint streaking and mottling green/yellow leaves caused by June yellows on the variety Blomidan.

PLATE 88. 2,4-D injury of fruit from application during bud initiation period.

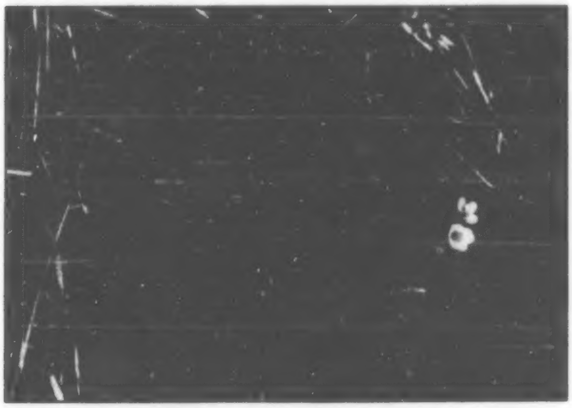

PLATE 89. Sinbar injury. Note interveinal chlorosis and necrosis of leaf.